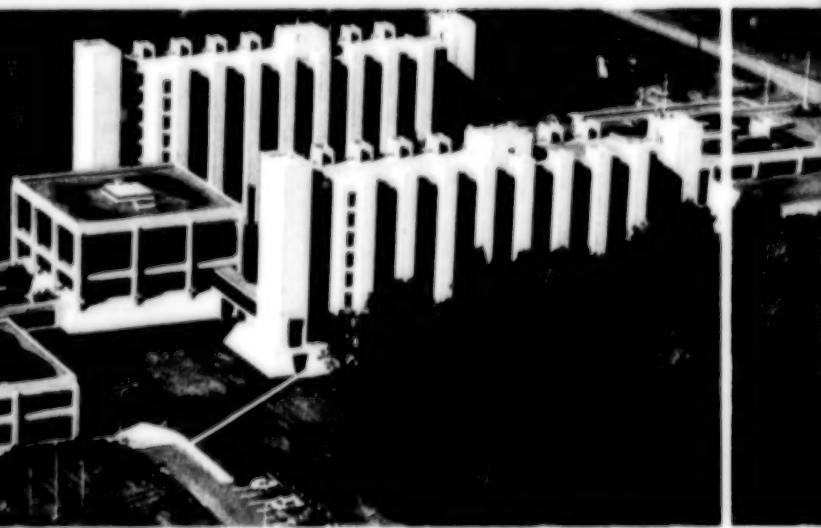
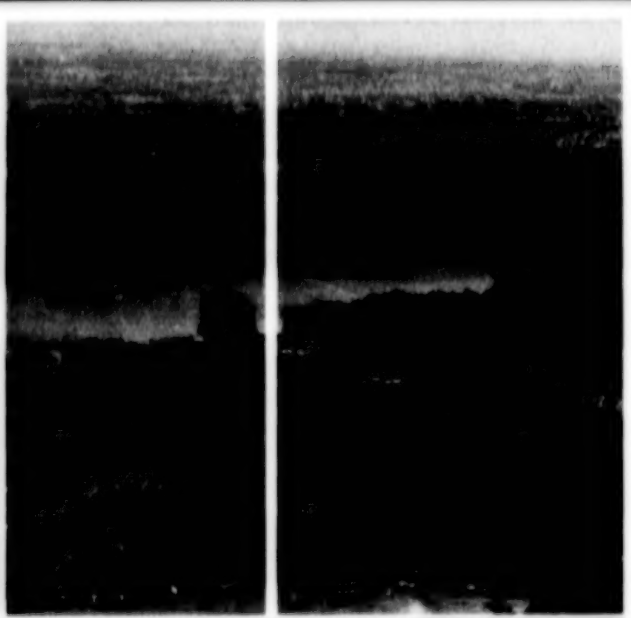




OCT 30 1987

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON QUESTIONED DOCUMENTS



FBI ACADEMY
QUANTICO, VIRGINIA
JULY 30 - AUGUST 1, 1985

COMPLETED

ORIGINAL

**Proceedings
of the
International Symposium
on
Questioned Documents**



Host

**Laboratory Division
Federal Bureau of Investigation**

July 30 - August 1, 1985

Forensic Science Research and Training Center

FBI Academy

Quantico, Virginia

NOTICE

This publication was prepared by the United States Government. Neither the United States Government nor the United States Department of Justice, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, mark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Published by: The Laboratory Division
James H. Geer
Assistant Director in Charge
Federal Bureau of Investigation
United States Department of Justice
Washington, D.C. 20535

International Standard Book Number 0-932115-04-7

Library of Congress Number 87-619826

Printed by the U.S. Government Printing Office

Cover: Aerial photograph of the FBI Academy by George February

FOREWORD

The FBI Laboratory hosted the "International Symposium on Questioned Documents" July 30 - August 1, 1985, at the Forensic Science Research and Training Center, Quantico, Virginia. There were 134 scientists from industry and government crime laboratories in the United States, Canada, Great Britain and West Germany.

Presentations were made by prominent scientists on topics such as paper, writing ink, printing ink and typewriter manufacturing and on methods for analysis of non-handwriting documents. There were also presentations on the examination of credit cards and photocopy machines and the examination of computer crimes by the questioned document examiner.

The exchange of ideas at this symposium will further generate the development of new methods for examining questioned documents through research. I thank all those who participated.

WILLIAM H. WEBSTER
Director

Program Organizing Committee

LYNNE BONJOUR
U. S. Postal Inspection Service Laboratory
BARRY L. BROWN
FBI Laboratory

THOMAS E. DEWAN
FBI Laboratory
KENNETH W. NIMMICH
FBI Laboratory

Session Moderators

LYNNE BONJOUR
U. S. Postal Inspection Service Laboratory
THOMAS E. DEWAN
FBI Laboratory
MANFRED HECKER
Bundeskriminalamt

CHARLES MCGINNIS
FBI Laboratory
DALE M. MOREAU
FBI Laboratory
PETER NOLAN
*Metropolitan Police Forensic
Science Laboratory*

Contents

FOREWORD	iii
SECTION I — LECTURES	1
Paper Manufacturing and Analysis—An Overview	3
<i>Griff Howell</i>	
Discussion	6
Writing Instruments, Inks, their Manufacture and Testing	7
<i>Robert R. Massey</i>	
Discussion	11
Document Printing Ink Composition and Analysis as Related to the Printing Process Used	13
<i>Robert W. Bassemir</i>	
Overview of Typewriter Ribbons and Inks	21
<i>Donald L. Elbert</i>	
Typewriter Manufacturing	25
<i>Donald W. Johns</i>	
The Classification of Photocopy Machines from Physical Characteristics	27
<i>Elizabeth L. James</i>	
Identification of Mechanical Printing Process Characteristics	33
<i>Robert G. Hacker</i>	
Analysis of Duplicator (Photocopy) Toners	49
<i>R. N. Totty, G. S. Kemp, B. German, G. S. Metcalfe and E. Hubbleday</i>	
Questioned Document Examination as Part of a Computer Crime Investigation	71
<i>Craig L. Schlinz</i>	
Laboratory Support in Counterfeiting Investigations	79
<i>John W. Piper</i>	
Methods for Examining Questioned Documents Using the Scanning Electron Microscope with Emphasis on Sequence of Writing Problems	83
<i>Peter J. Nolan</i>	
Computerized Reporting	97
<i>Manfred Hecker</i>	
ESDA Safety	101
<i>Franklin P. Lundblad</i>	
Typewriter Impression Comparison Study Considerations	105
<i>Arthur Schlang</i>	
Laser Scanning of Inks	111
<i>D. Varshneya, L. A. Jeffers and M. G. Noblett</i>	
FBI Laboratory Divisions National Stolen Art File	119
<i>C. Thomas Spitzer</i>	
Discussion	121
SECTION II — EXTENDED ABSTRACTS	123
Differentiation of Inks through Laser Technology	125
<i>M. P. Gryzik and M. Black</i>	
The Examination of Altered and Counterfeit Credit Cards	127
<i>R. P. Johnson</i>	
Sequence of Writing—Pencil and Porous Tip Pen	129
<i>D. R. Howes</i>	
Experiments in Ball Point Ink Aging Using Infrared Spectroscopy	131
<i>H. J. Humecki</i>	

Classifying the Computer Printed Document	137
<i>J. Winchester</i>	
Preliminary Examination of Machine Copier Toners by Infrared Spectrophotometry and Pyrolysis/Gas Chromatography	139
<i>J. Zimmerman, M. J. Kimmelt and D. Mooney</i>	
Pyrolysis GC/MS of Inks and Paper in Document Identification	141
<i>T. P. Wampler and E. J. Levy</i>	
Methods Concerning Classification and Identification of Photocopies	145
<i>H. G. Heuser</i>	
Statistical Interpretation of Metal Beads Imparted to the Printing Surface of IBM Selectric Type Elements	159
<i>P. Marchand</i>	
The Feasibility of Classifying Modern Printwheel Typestyles	163
<i>J. E. Behrendt and R. H. Muelhberger</i>	
Facsimile Copies as Document Evidence	171
<i>T. E. W. Goyne</i>	
Video Spectroscanner System: Quality Enhancement and Low Cost Improvement	173
<i>S. Rivera and E. Flores</i>	
The Study of Inverted Mirror Image Writings Through the Use of the Video Spectral Comparator ...	175
<i>C. J. Raichle</i>	
ESDA and the Post-it® Note	177
<i>J. S. Tweedy</i>	
Video Image Enhancement with the Foster and Freeman Digital Image Processing System	179
<i>P. D. Bouffard</i>	
Suspect Art/Suspect Documents: A Case Study Of Parallel Techniques and Examinations	181
<i>C. Mercer</i>	
SECTION III — PANEL DISCUSSION	183
Training the Document Examiner	185
<i>Lynne Borjour, David Crown, Thomas E. Dewan, Manfred Hecker, A. G. Leslie and Richard Toddy</i>	
PARTICIPANTS	187
AUTHOR INDEX	189
SUBJECT INDEX	191

SECTION I
LECTURES

BLANK PAGE

PAPER MANUFACTURING AND ANALYSIS—AN OVERVIEW

Griff Howell

Fox River Paper Company
Appleton, Wisconsin

Paper! Paper is taken for granted by many of us. Paper is such a common material and is used for so many different purposes that we usually accept it without thought about how or from what it is made. Because it must do so many jobs for us, the manufacturer must choose the fibers and other ingredients carefully and then process them in such a fashion that the resulting products are the very best for their designed purposes. This means that very few specific statements can be made about what goes into paper and how paper is made.

Paper comes in many forms and sizes and has a multitude of uses. Its versatility is nearly unlimited. Just think for a moment. We use paper cups and plates; we cover walls, communicate, keep records and blow our noses in paper.

In general, paper comes in two forms. The two broad subdivisions of paper are paper and paperboard. The distinction is not very clear, but generally speaking, paper is lighter in weight, thinner and more flexible than paperboard. Its main uses are for printing, writing and wrapping. Paperboard is heavier, thicker and more rigid. It is used for containers, boxes and special food board.

Paper is defined as a "felted sheet of fibers formed on a fine screen from a water suspension." Paper's origin, history, recipe, manufacturing process and analysis will be reviewed here. General information will be discussed.

Paper gets its name from a reed plant called papyrus, which is native to the Nile region of Egypt. The pith of papyrus was sliced and pressed into matted sheets and used by ancient Egyptians, Greeks and Romans for writing material. However, complete fiber separation, which is characteristic of papermaking, was absent.

It is generally accepted that paper was invented in 105 A.D. in China by T'sai Lun. He made paper by hand, using a pulp mixture of beaten and saturated silk, mulberry and bamboo. He then dipped a mold, probably made of bamboo and cloth, into the pulp, formed a sheet, dried it in the sun and when removed, it was ready to use. The making of paper, from whatever available resources, migrated from China to Persia, Egypt, Spain, Italy, France, Germany, England and to America at Philadelphia in 1690.

A chronological order of events of papermaking history is as follows:

- 1600s - 1800 — Called paper renaissance—France was the leader with the best papermakers and equipment.
- 1750 — Approximate date of invention of a European wire wove hand-making mold in

England. Also about this time cotton rags began to be an alternative raw material source in Europe.

- 1798 — Patent issued to Nicholas Louis Robert for first continuous papermaking machine.
- 1803 — Patents issued to Fourdrinier brothers for improved continuous paper machine design in England.
- 1809 — Patent issued to John Dickinson for cylinder machine in England.
- 1817 — First cylinder machine in America.
- 1827 — First Fourdrinier machine in America.
- 1828 — Straw and old rags became raw material for papermaking in the United States.
- 1840 — Ground wood process developed in Germany.
- 1850 - 1930 — Chemical processes developed in fiber preparation, including soda process, sulfite pulping, kraft process, and the Mitscherlich process. These will be discussed later.

It is practically impossible to discuss papermaking without sooner or later talking about the closely related art of printing. In 1450, Gutenberg invented movable type for printing. The development of the art of printing created an unprecedented demand for paper. This interrelationship was responsible for a greatly accelerated rate of improvement in the equipment of papermaking and a search for new raw materials. The invention of printing and the accelerated interest in learning and communicating that followed in the 15th and 16th centuries touched off a raw material supply problem.

Throughout history, all materials used to make paper, whether hemp, bamboo, linen, cotton rags or rice, had one common characteristic—cellulose. Cellulose is the substance in plant fibers that determines the character of the fiber and permits its use in papermaking. Cellulose is a carbohydrate, meaning it is composed of carbon, hydrogen and oxygen. Cellulose is also a polysaccharide, meaning that it contains many sugar units.

The chemical formula for cellulose is $(C_6H_{10}O_5)_n$, where n shows the number of repeating sugar units or degree of polymerization. Cellulose is a polymer only of glucose. A number of shorter chained polysaccharides are known together as hemicelluloses. Hemicelluloses are polymers of five different sugars namely glucose, mannose, galactose, xylose and arabinose. Compared to cellulose, the hemicelluloses are easily changed and dissolved, so that their level is always less in the pulp than in the original wood. The purest natural form of cellulose is cotton, which is used in

very high grade papers.

Anselm Payen, a French chemist, identified cellulose as a separate entity in wood. In North America, the preferred raw material for papermaking is wood. The primary reason is its availability, but wood fibers are also versatile and economical to produce. Examples of hardwood species are aspen, birch, beech and oak. Examples of softwoods are black and white spruce, balsam and Douglas fir, western hemlock and various pines that include jack pine, slash pine and loblolly pine. Wood is composed of the carbohydrates (cellulose and hemicellulose), lignin and extractives.

Woody plants contain lignin, the material that cements the fibers together. This material must be removed in the pulping processes to free the cellulose fibers for papermaking processes. Lignin amounts to about 21% in hardwoods and 25% in softwoods.

A number of other diverse substances, called extractives, may be present and must be removed. Falling into this category are resin acids, fatty acids, turpentine, compounds and alcohols. Most of these substances are soluble in water or organic solvents. Extractives exist in wood at a level between 2% and 8%.

Cellulose exists at different levels in various plant fibers, for example, in cotton, 98%; flax, 85%; wood, 50%; and grass fibers, 30%. Pulping can be defined as the removal of noncellulosic constituents in the preparation of fibrous raw material for papermaking. Pulping can be carried out by mechanical or chemical means or by a combination of the two. Whatever the method, there is a loss of wood substance.

The most easily produced papermaking fiber is ground wood because no chemicals are involved. Pulps made without chemical addition are called mechanical pulps. The paper manufactured this way has a high level of impurities and is most commonly used for newspapers and pencil tablets. Because lignin, for the most part, is not removed this type of paper will yellow quickly with age.

Another kind of pulp that is not particularly pure is chemi-mechanical. Some chemical is used but mechanical action is used to separate the fibers. Papers made with this type of pulp are used for roofing and flooring materials and the corrugated layer in paper-board boxes.

Even when wood is pulped to the point where the chips require little or no mechanical action, this chemical pulp may be made to a variety of purifications and yields. All of them require pressurized reaction vessels called digesters to permit the use of high temperatures. A number of different chemicals can also be used to soften and solubilize the lignin. The most versatile of these chemical processes is called the kraft process, from the Swedish word meaning strong. Much of our white printing and bond papers contain strong, bleached kraft fibers. Other chemical means of pulping are the soda and sulfite processes.

Today's bleaching technology permits the whitening of all pulps. While the primary purpose of bleaching is to whiten the cellulose fibers, it also finishes the

purification process begun in the pulping stage. Gaseous chlorine and other chemicals that make the pulp white are used for this purpose. Chlorine reacts with most of the lignin that remains from the chemical pulping. The resulting compounds of lignin are then washed away with other chemical additives.

Paper can be composed not only of plant fibers, but also of animal fibers (wool, silk), mineral fibers (glass) and synthetic fibers. Other components within paper are nonfibrous materials. Nonfibrous materials fall into two categories, inert materials and chemicals. Inert materials such as titanium dioxide, clays, calcium carbonate and talc are used as part of the sheet furnish. A variety of chemicals are used throughout the pulping and papermaking processes.

There are generally two accepted categories of chemical additives used in pulping and papermaking: process control chemicals and functional chemicals. Examples of the process control chemicals are salts, alkalis, acids, alum, slimicides, defoamers, retention aids and drainage aids. Examples of functional chemicals are dry and wet strength additives, internal sizing agents, optical brighteners and surfactants.

The basic raw material of fibrous and nonfibrous material can seldom be formed into paper without some physical processing. This means that the tiny cellulose fibers must be broken, cut and smashed into even finer particles so that there are more places for these miniature threads to bond to each other. This processing is called beating or refining and many machines have been invented to accomplish it. Almost all of them call for stirring the ingredients with water so that the mixture can be pumped and handled like a liquid. From this point, the mixture is known as stock.

When the fibers are sufficiently refined, other material may be included to give the paper certain needed properties. For the simplest jobs, such as wrapping articles, the paper may need only something to make the surface a bit resistant to wetting. This material is called size and is used on most papers. It is usually in the form of rosin from pine wood, but can be synthetic as well. This material is set in the sheet with alum and allows us to write on paper without ink blotting or feathering. Dyes may also be included in the sheet to give a desired color.

When the stock is properly prepared, it is formed into paper in a continuous web on a paper machine. Between the stock preparation room and paper machine room, the stock is usually piped through refiners and/or Jordans, which can be adjusted to give the finished paper the exact properties required. After passing through the Jordans, the stock suspension is screened through stock cleaners that remove dirt and other foreign materials.

Of course, the most common kind of paper machine is called the Fourdrinier. This machine forms the paper on a long endless belt made of wire or plastic mesh. This belt, called a wire, is strung on two rolls that act as pulleys and cause the wire to revolve with the top

side on a long, level plane supported by small revolving rolls or plastic plates. The stock is diluted with water to a level of about .5% consistency before entering the machine. The mixture comes out onto the moving screen from the headbox. As the screen travels forward, the water drains away through the returning portion of the wire and into a pit. By the time the wire reaches the roll where it reverses and returns to the headbox, the stock has become a very wet web of paper, which has just enough strength to hold together on its own, and is laid on a wool and/or synthetic blanket called a felt. It is then passed between a series of press rolls. The felts are also endless belts and carry the sheet along until it is dry enough to support its own weight. The rest of the water must be removed by heat drying, which is done by passing the continuous sheet over and under hollow revolving cylinders or dryer cans. These contain steam that provides the necessary heat to evaporate the water out of the paper. The finished paper is wound on rolls with 4 to 6% moisture. Water is removed, therefore, by drainage, pressing and heat.

The other kind of paper machine is called a cylinder machine. In this case, wire mesh is wrapped around a hollow, cylindrical framework and the roll rotates horizontally in a vat, which is slightly larger than the cylinder but not deep enough to cover it. When paper stock is piped into the vat and the roll is revolved, the solids stick to the wire mesh and form a sheet. This is removed when it comes in contact with a felt, which is run against the upper part of the roll. This machine usually consists of a number of vats and rolls. As each sheet is removed, it joins the preceding sheets and becomes one multi-ply sheet. The finished product may have dark paper making up the inside plies and more expensive white layers on one or both exposed surfaces. Lightweight boxes for packaging items like clothing and food products are often made from this kind of paper.

Paper leaving the paper machine may have its properties and appearance changed considerably in the finishing operation. It may be changed from roll to sheet form in cutters or sheeters, which take the paper from many rolls and cut it into required sizes. Here it is also trimmed into sizes used by printers or converted into other paper products.

One of the things that can be done to the sheet of paper while on the Fourdrinier wire that was not previously mentioned, is to run a patterned roll on top of the sheet. Thus are obtained watermarks, which may be a trade name or a pattern that shows up when the paper is held up to the light. This type of roll is called a dandy or dandy roll.

Watermarks have existed since the time of handmade mold form sheets. The earliest known watermark dates back to 1282 in Italy. Through the years, various forms were depicted such as religious symbols, simple ovals, circles and triangles, tools, ships, plants, flowers and trees. The original concept of this type of roll is credited to John Marshall in 1826.

There are two types of dandy watermarks. The first is a wire mark. A raised design soldered to the dandy

roll is pressed into the wet sheet of paper. Because this disarranges the fibers and thins the stock at that point in the sheet, the designed area is rendered more translucent than the surrounding part of the sheet.

The second type of watermark produced by a dandy is the shaded mark. This watermark is put into the paper by a dandy that has a design pressed into the wire of the dandy itself. The watermark areas become more opaque than the rest of the sheet.

Watermarks can be put into the sheet in another fashion. This is called the rubber-stamp method. It occurs further on in the machine when the sheet is much drier and a rubber design can be pressed into the sheet, causing the sheet to become more translucent.

Another method of watermarking is called Customark.[®] This technique in the art of watermarking is a chemical process that produces a translucent mark. The chemical mark is applied to the paper after it has been manufactured.

Mill brand watermarks may identify the manufacturer. Many mill brands are listed in directories, such as Grade Finders, Lockwoods and Posts. A watermark can help in the identification process. If watermarks are a private brand, the manufacturer of dandy rolls may be able to identify it. In the United States there are about six companies. These companies keep very good records and are frequently called on to help in forensic problems.

Some mill brands and private watermarked sheets contain a symbol or marks that identify it to a particular year of manufacture. For example, Government watermark sheets actually show by number the year of manufacture.

Our Government specifies other security or safety features on some of the papers that are ordered. What comes to mind is currency, passport and social security card base stocks. For example, the social security card paper "shall be surface treated or impregnated so as to have certain chemical sensitivities such that it shall provide visual reaction to attempted alteration with the following chemicals: organic solvents, acids, bases, bleaches and sodium bisulfite." Also, the paper must contain multicolor planchettes. To evaluate, five drops of various chemicals are placed on a sample sheet. A visual reaction shall be judged as present or absent.

The analysis of paper ranges from the very simple to the most sophisticated. For example, analysis can be as simple as determining the thickness of the sheet or as sophisticated as using transmitted electron microscopy or the scanning electron microscope. Testing of sheets can be destructive or nondestructive. Certainly, if nondestructive evaluation is required, many methods are disruptive or disfiguring to the sample. Because fiber is the major material in paper, the analysis of fiber is a very important test. Fiber microscopy includes species identification and can also determine pulping and bleaching processes. Standard methods are available from:

TAPPI—Technical Association of the Pulp and Paper Industry

CPPA-TS—Canadian Pulp and Paper Association—Technical Section

SCAN—Scandinavian Pulp, Paper and Board Testing Committee

ASTM—American Society for Testing and Materials

BPBMA—British Paper and Board Makers Association

APPITA—Australian Pulp and Paper Industry Technical Association.

Paper testing falls into two categories, physical and chemical methods. Physical methods are subdivided into four groups:

1. Mechanical and strength properties: Examples are basis weight, fold, tear, thickness, burst and softness.

2. Surface properties: Examples are smoothness, pick resistance and erasing.

3. Optical properties: Examples are brightness, opacity, color and gloss.

4. Permeability to fluids: Examples are degree of sizing, oil resistance and air resistance.

Chemical properties of paper can be derived from the fibrous and nonfibrous materials that lend particular attributes to a given kind of paper.

Paper does play such an important part in our lives. It is reported that more than 600 pounds of paper are

used per person each year in the United States. The paper industry is growing steadily and increases by about 3 to 4% a year. It appears assured that man's history, progress and development will continue to be recorded and communicated on paper.

DISCUSSION

Question: All the custom marks that I am familiar with are light marks. Do you have any dark custom marks?

Howell: A custom mark is a chemical water mark. You cannot make the area more shaded, but you can make it more translucent; then it is called a wire mark.

Humeckee: Two questions. First, when you use recycled pulp, how do you know that you are getting cotton and not synthetics? And second, what synthetics have an effect on the paper-making process?

Howell: First, I did not mean to give the impression that we use waste paper or recycled paper. Waste paper is used, however, in the paper industry. Second, in answer to the question on synthetics, man-made fibers can be added to a sheet to give it certain security features.

WRITING INSTRUMENTS, INKS, THEIR MANUFACTURE AND TESTING

Robert R. Massey

Anja/Scripto, Inc.
Monrovia, California

Two hundred years ago, people were writing with quill pens. The signers of our Declaration of Independence affixed their signatures to that document with a quill pen. Needless to say, the writing instrument has come a long way in the past 200 years, as the need for document analysis also has come a long way. As more and more writing instruments from Japan and Europe are brought on the market, the more difficult the task of document analysis becomes. Hopefully, providing you, the forensic scientist, with an understanding of the different inks in these instruments and how they are manufactured, will make your task of document analysis easier.

The topic of writing instruments covers a lot of ground. There are many different types of writing instruments: ball point pens, roller ball pens, fiber nib pens, extruded plastic nib pens, fountain pens, and the newest type of pen on the market, the erasable ball point pen. As each one of these instruments differs from the next, so do the inks used in these instruments. Also, different manufacturing procedures and analytical testing procedures are required for these different types of inks.

In 1983, the latest year we have data for, 3.2 billion writing instruments were sold in the United States. Approximately 2.1 billion, or 65% of these were ball point pens; I will first cover these writing instruments and their inks because of the high probability that ball point pen writing will be encountered in any forensic document analysis.

Most people in the industry consider a Hungarian scientist, Ladislav Biro, to be the father of the ball point pen. Actually, the first patent issued for a ball point pen went to an American inventor, John Loud, in 1888. His invention was never marketed because an accurate method for making the ball point was not available and a suitable ink to use in it did not exist. Biro, in Buenos Aires in 1935, found a way to accurately grind a metal ball that would rotate smoothly in a brass socket. He used what we now call an oil-based ink, and achieved acceptable results. Work on perfecting the ball point pen took a "back seat" to World War II, and it wasn't until 1945 that the Reynolds Pen Company hit the market with a ball point pen. This early pen sold for an amazingly high \$12.50, at Gimbels Department Store where it was first introduced.

Two basic types of inks have been used in ball point pens. The ink used in the early version of pens was oil-based ink; an improved ink then came along that was referred to as quick-dry or glycol ink.

The early oil-based inks were actually no more than printing inks produced primarily by printing ink com-

panies. Typical formulations contained a basic dye base, 10 to 15 parts, dissolved in about twice as much fatty acid, usually oleic acid. This would form an oleate, which then was thinned with another oil, such as castor oil. A rosin or rosin acid ester was sometimes used to adjust the viscosity of the ink. The oil-based ink dried by absorption of the oil vehicle into the porous paper substrate. The ink solvent or carrier did not evaporate, so the total ink stayed on or in the paper. This would cause smearing, transfer from one page to the next, and strike-through or penetration of the color into or through the paper.

In the early 1950s, the so-called quick dry or glycol-based inks were introduced. These are far superior to the oil-based inks because of their drying characteristics. The ink is absorbed into the porous paper, making it appear to be dry in a matter of seconds. These inks also dry by the evaporation of the major solvents because of the extremely thin film that the ball deposits on the paper. Also, some of the glycol-based inks dry by absorption of moisture from the paper and from the atmosphere. This results in precipitation of the water-insoluble dyes from the ink film. It seems that solvent evaporation is the most significant factor involved in the drying process since there is a direct relationship between the vapor pressure of the solvent and the time required for the ink to dry.

Although these solvents are not considered volatile, their vapor pressures are high enough to permit them to evaporate from the thin layer of ink that is put down on the paper. Typical solvents used in quick dry or glycol-based inks include:

Ethylene glycol	Dipropylene glycol
1, 2- Propylene glycol	Glycerine
1, 3- Butylene glycol	Phenoxyethanol
Hexylene glycol	Benzyl alcohol
Octylene glycol	Ethylene glycol
Diethylene glycol	monomethylether
Triethylene glycol	Diethylene glycol
	monomethylether

These solvents can be used singularly or as mixtures in ball point pens.

The dyes used in the oil-based inks were primarily basic dye bases such as methyl violet, Victoria blue, rhodamine, Victoria green, and auramine. For black inks, induline or nigrosine bases were used. These dyes need a fatty acid, like oleic acid, to help solubilize them in the oils. Also, their fastness properties leave a lot to be desired. They usually have poor resistance to light, fading if exposed to any light for a period of time.

Some of these early inks also contained carbon black or graphite to increase permanence.

In contrast, the glycol-based inks usually are made with metalized dyestuffs that are structured for high solubility in glycols and similar solvents. The most popular dyes are the blues based on copper phthalocyanine. These dyes are prepared by sulfonating or chlorosulfonating copper phthalocyanine pigments and reacting the sulfonic acids with amines to form colored sulfonic acid salts or sulfonamides.

These dyes have very good light fastness properties and very high solubilities in the glycol solvents. Other premetalized dyes, such as reds, greens and yellows, are produced in a similar manner and are used to achieve the shade of ink desired. Also, some of the oil-based dyes are used in low percentages as shading dyes because of their usually intense color, but a fatty acid must be used to solubilize these dyes in the glycol solvents.

Other chemicals used in ball pen inks today are resins for viscosity adjustment, lubricants for the ball and proprietary additives that contribute to good writing quality.

Ink manufacturing procedures can vary from one manufacturer to another, but the basic mixing concepts apply to all. Usually the ink is made in large stainless steel kettles, capable of being heated by either steam or oil. The glycol solvents are weighed into the kettle and brought up to mixing temperature. Then a resin is added and allowed to dissolve and mix in completely. Next come the other ingredients of the vehicle, namely the acids, lubricants and other additives. Finally, the dyes are added and allowed to dissolve completely in the vehicle. This operation takes about 6 hours to complete. Next, an in-process viscosity check is taken and any adjustments to the viscosity are made. Then, the ink is pumped from the kettle through filters and into drums.

We use many different analytical techniques to check both the incoming raw materials and the finished ball pen ink. Some of these analytical procedures are applicable to analyzing inks on a paper substrate or inks taken from the substrate.

Some of the analytical procedures we use are:

1. Infrared spectroscopy, which is useful in obtaining a "fingerprint" of the total ink. A total ink spectrum, or fingerprint, is conveniently obtained using disposable infrared cells, since ball pen inks are very difficult to clean from standard infrared cells. Alternately, a small quantity of the total ink can be mixed with powdered potassium bromide and formed under pressure into a pellet or disc. This disc can then serve as the sample and as the infrared cell from which the spectrum is obtained.

The solid portion of the ink can also be examined in the infrared region of the spectrum by removing the solvent from the powdered potassium bromide ink mixture before forming the disc. Heating the mixture for a period of time and forming the disc with vacuum will remove the solvents. Infrared is also useful for iden-

tification of individual components that have been separated from the total ink by various means.

2. Visible absorption, which is useful for identification of the dyes contained in a ball pen ink. The visible absorption may be readily obtained from a diluted solution of the total ink. Standard pyrex or quartz cells can be used with these diluted solutions of ball pen inks. Examination of the visible absorption will permit the determination of the concentration of the dyes present in a ball pen ink, provided that the identities of the dyes have been established. An accurately weighed ink sample and accurately diluted solution are required for this.

3. Thin layer chromatography and paper chromatography, which are used to separate and identify dye components and to detect the presence of pigmented materials in the ink. An accurately weighed amount of ink is diluted with a solvent, then spotted on the thin layer sheet. The sheet is put into an oven at 105°C for a few minutes to evaporate the solvent. Then it is put between glass plates and placed vertically in a solvent bath. As the solvent moves up the sheet, it separates the dyes as they are carried along. If any pigmented materials are present, they will tend to stay at the bottom of the sheet. Viewing the sheet under ultraviolet light is also useful, since some dyes will fluoresce under ultraviolet light.

4. Microscopic examination of the ink to determine if any pigmented materials are in the ink. This must be done at a magnification of 100x to 200x because the pigment particles are very small. We also look for any foreign matter, dye crystals or phase separation in the ink.

5. Vapor phase gas chromatography, which is used to separate and identify the volatile solvents in the ink. Using the term "volatile," however, is a bit misleading since vapor phase chromatography, as it is currently used, permits routine operation at temperatures of 350°C to 400°C (650°F to 750°F). At these high temperatures, solvents that are referred to as non-volatile, particularly those oils in the oil-based inks, can be vaporized, separated and detected by vapor phase gas chromatography. For example, oleic acid, actually a mixture of fatty acids, and even mineral oil, are detectable. By comparing the retention times of the various components using two or more chromatographic columns will permit the identification of the different solvent components in an ink. More accurate and positive identification can be made by trapping the individual components as they exit from the column and analyzing them using an infrared spectrophotometer or mass spectrometer.

Vapor phase gas chromatography often shows the presence of impurities from the raw materials used in the preparation of the ink. Dyes, for example, sometimes hold tenaciously to traces of solvents they have contacted during their preparation. These traces can sometimes be used to determine the source of a particular dye used in a ball pen ink. Also, sometimes a material that is itself not volatilized during chromatog-

raphy will undergo partial decomposition during analysis of an ink for solvent content and produce specific peaks in the chromatograph. These peaks may sometimes give a clue to the source of a material.

For example, some dye manufacturers use a small amount of an oil or glycol as a dedusting agent in their dyes. Also, different amines can be used in the dyes as a solubilizing agent. These ingredients can be detected on the gas chromatograph as extra peaks and lead to the identification of the source of the dye.

This might be useful in surface analysis. In fact, pyrolysis attachments are available for vapor phase gas chromatography equipment and have been used to deliberately break down solid materials and to separate the decomposition products for identification, or at least to obtain characteristic chromatographs of the degradation products.

These five analytical methods—infrared spectroscopy, ultraviolet-visible spectroscopy, thin layer chromatography, microscopic examination, and vapor phase gas chromatography—can be useful to the forensic scientist in examining the ink from a document.

Other procedures that we use on our inks are pH value determinations; tests for surface tension, viscosity, moisture content, water resistance, light resistance, bleach resistance, drying time, aging characteristics, writing properties and starting characteristics; and compatibility studies to ensure that the various component materials are stable with respect to each other in the ball point pen unit.

We do not have the capability of neutron activation, but this is a very important analytical procedure to the forensic scientist because most manufacturers are cooperating with the Bureau of Alcohol, Tobacco and Firearms (ATF), by putting rare earth date tags in their inks. Every July 1, we change our date tag to that suggested by the ATF. This way, the year that an ink was manufactured can easily be determined.

The next category of inks I would like to discuss are collectively called marker inks. These inks are used in a wide variety of our writing instruments. Although we make different inks for the different types of markers, they are all basically water-based inks. Therefore, quality control procedures and analytical testing of the inks are much the same.

Roller ball pens are becoming more and more popular. The roller ball pen uses a metal ball that rotates in a plastic or stainless steel socket. The ink is water based and is held in a cellulose acetate or polyester fiber reservoir, which looks much like a cigarette filter but is about 4 inches long. The ink is fed from the reservoir to the ball by a feeder rod. The feeder rod is a fiber with one end embedded in the reservoir and the other end in the point. The ink is drawn by capillary action out of the reservoir, through the feeder rod to the ball, and is deposited on the paper by the rotating ball.

A newer version of the roller ball pen does not require a fiber reservoir. The ink is held freely in the barrel and point seepage and leaking are controlled by

a series of small baffles at the nose of the pen. This is much like a fountain pen, but the point and feeder rod are still like the roller ball pen with a fiber reservoir.

Roller ball ink is a water-based ink, as I stated before. The main solvent is deionized water, but other glycol solvents are also used. These solvents, ethylene glycol, diethylene glycol, triethylene glycol, glycerine, etc., are used at a concentration of a few percent to as much as 30% by weight of the total ink formula. These solvents are used to build viscosity, to keep the point from drying out and to produce smoothness of writing.

The dyes used in roller pen inks are water-soluble dyes. These can be acid dyes, direct dyes or basic dyes. Acid dyes are salts of carboxylic or sulfonic acid with an inorganic base. The chromophore, or colored portion of the molecule, is attached to the acid end, therefore it is called an acid dye. This name can be misleading since an acid dye dissolved in water will yield a basic pH. This is caused by the inorganic base, which is stronger than the acid. Acid dyes are usually tinctorially strong and brilliant, but their light and water resistance is not good.

Basic dyes have organic bases, which contain the chromophores that are reacted with a strong acid to form a salt. Basic dyes in solutions with water will yield an acid pH value because the acid is stronger than the base. Basic dyes have fair resistance to light and water, but their solubility is not good.

Direct dyes are very similar to acid dyes in their structure, but their name comes from the textile industry. When dying with an acid dye, an acid is added to the dye bath to help the dye react with the material. A direct dye does not need additives to react directly with the material, hence, the name direct dye. Direct dyes have good resistance to light and water, but are not quite as strong in color or brilliance as the acid dyes.

Typically, we try to reach a happy medium by using acid dyes and direct dyes in the ink—the acid dyes to achieve a deep, brilliant color and the direct dyes for the necessary light and water resistance.

We also add other materials for shelf stability, point lubrication, pH adjustment and wetting properties.

Fiber nib pens have been around for about 20 years. The mechanics of the pen are essentially the same as the roller ball pen, except for the nib or point. Instead of a roller ball, it has a rod made from bonded fiber and shaped to a point. This also acts as the feeder rod; one end is embedded in the reservoir, and the other end extends beyond the end of the barrel. This end is pointed and is the writing nib. Some fiber nibs are very wide in diameter and are just pressed into the nose of the barrel; others are thinner and need a plastic adapter around them to fit in the barrel.

Three types of ink are used in the fiber nib pens. These are water-washable, water-resistant and permanent inks. The water-washable and water-resistant inks are water based. The main solvent is deionized water and, as in the roller ball inks, glycol solvents are also used.

Water-washable inks are just that; they are formu-

lated to wash off easily. This is accomplished by the choice of dyes used in the ink system. Because the acid dyes have poor resistance to water and light, these are the dyes that are used. Through testing of individual dyes, the least water-resistant dyes are selected to be used singularly or in mixtures to achieve the desired shade of color.

Water-resistant inks are formulated to stand up to water spills or exposure to light sources. Here, we use direct dyes or basic dyes, either singularly or in mixtures, to achieve the desired color and fastness properties. Sometimes a small amount of an acid dye will be used as a shading dye.

Again, in these two types of fiber nib ink, we add materials for shelf stability, pH adjustment and wetting properties.

The third type of fiber nib ink is permanent ink. This is not a water-based ink, but is alcohol or xylene based. This ink is used to mark on glass, plastic, metal or paper, where water and light resistance is critical, as in a lab marker.

The solvents are usually N-propyl alcohol or xylene, with a resin incorporated for adherence to nonporous substrates. Dyes used are mainly premetalized dyes that are readily soluble in the solvents, but basic dye bases are also used. As before, the basic dye bases need a fatty acid present to solubilize them in the solvent. A polyester reservoir is recommended because the solvents tend to attack cellulose acetate reservoirs. This can cause shrinkage of the reservoir, resulting in ink being squeezed out of the nose end of the barrel.

The next type of writing instrument I would like to cover is the extruded plastic nib pen. The writing nib in these pens is an extruded plastic, usually polyacetal, more commonly known as Delrin or Celcon. This nib is extruded and cut off in lengths of approximately 1 to 1-1/2 in. The center of the nib is like a honeycomb, with open capillary columns that the ink can travel through. We make two types of extruded plastic nib pens. The ultrafine or razor point is a very fine nib from .5 to 1 mm in diameter. We also make a hard head nib that is from 2 to 3 mm in diameter.

The basic unit is the same as the fiber nib pen. The nib is embedded in a reservoir with the other end extending beyond the end of the barrel; this becomes the actual writing nib. Ink is carried by capillary action from the reservoir through the nib, and onto the paper substrate.

The ink is a water-based ink that also contains some glycol solvents. The dyes used in this ink are usually direct dyes with small amounts of acid dyes for shading. The ink is primarily used for writing, so good water and light resistance is required. Again, this is accomplished by the choice of direct dyes, since these have good water and light resistance. Other materials added to the ink are corrosion inhibitors, wetting agents and preservatives for longer shelf life. The needle point nibs usually have a metal adapter around them to facilitate a snug fit of the nib into the barrel, hence the need for a corrosion inhibitor.

The critical measurement in extruded plastic nib ink is the surface tension. A fine balance must be obtained for the instrument to function properly. If the surface tension is too low, typically less than 35 dynes/cm², the ink will have a tendency to drain back out of the nib when the pen is kept in a position with the nib or point up. The pen will not write until the ink has a chance to move back into the nib. Also, if the surface tension is too high, then ink will tend to stay in the reservoir and not move down into the nib after it is loaded. Typically, we try to keep the surface tension between 40 and 50 dynes/cm².

The surface tension can be lowered by the addition of a surfactant, but there is nothing we can add to raise the surface tension. The dyes that are used affect surface tension, so we test the dyes to ensure that they will yield a high enough surface tension when dissolved in the ink vehicle.

The analytical procedures used for ball pen inks also apply to the marker inks. We use infrared spectroscopy, ultraviolet visible spectroscopy, microscopic examination, thin layer chromatography, and vapor phase gas chromatography to evaluate the inks. As before, these five analytical procedures should be of special interest to the forensic scientist, since the different inks can be identified and categorized using these tools.

Also, we measure surface tension, pH values, water resistance, light resistance, drying time on paper and cap-off time (the amount of time a marker can be left with the cap off and still function).

The manufacturing procedures for marker inks are much the same as for ball pen inks. We manufacture the inks in stainless steel kettles that are capable of being heated with either steam or oil. First the deionized water is added, then any required glycols or other additives. This mixture is brought up to processing temperature, about 100°F, then the dyes are added and allowed to dissolve. The only in-process testing is usually for a pH adjustment. Then the ink is pumped through filters and into drums. Typically, the fiber nib ink is filtered through 3-micron filters, and the extruded plastic nib ink is filtered through 1-micron filters. The extruded plastic nib ink needs a finer filter because the capillary holes in the nib are straight and fewer in number than in the fiber nib, hence they will plug easier.

The oldest of the writing instruments are the fountain pens, which are similar to the old quill pens. Fountain pens were first introduced around 1880. Before this, many types of pens used a metal nib, but these had serious drawbacks, such as scratchy writing, leaking, smears and general unpredictability.

Louis E. Waterman is credited with perfecting the fountain pen. He did this by inventing the fissure feed, an ink flow based on capillary action. He called his pens "Ideal," and they were made of hard rubber with gold and iridium writing nibs. The interior barrel provided a reservoir for the ink and was filled with an eyedropper. Next, self-filling pens were invented, followed by the replaceable cartridge reservoir.

Fountain pen ink today is water based. It is similar to the water-based marker ink that has already been discussed. It contains deionized water, sometimes a glycol-type solvent, corrosion inhibitors and dyes or pigments. The dyes are water soluble, usually acid or direct dyes. The ink is formulated to give good light fastness and reasonable water resistance. Pigments are also occasionally used to give better fastness properties.

The sale of fountain pens declined steadily after the introduction of the ball point pen in the late 1940s. Oddly enough, though, sales have sharply increased since 1981. It seems that more and more people are using fountain pens because of the distinctive writing. One can personalize their handwriting by using a fountain pen, because of the shape of the metal nib.

The newest pens on the market today are the erasable ball point pens. These pens were first introduced in the late 1970s, and have slowly increased in sales during the past 5 years.

The pen itself is very similar to a ball point pen. It uses a ball point, a metal cartridge and a plastic barrel, but here the similarity stops. The cartridge in an erasable pen is usually pressurized since the ink is much higher in viscosity than normal ball pen ink. This also allows the pen to be used at any writing angle, even upside-down.

The ink is also very different in its makeup. An elastomer is dissolved in a hydrocarbon solvent. To this, proprietary materials are added to help smoothness of writing, startability and long term shelf stability. The main coloring material in these inks is usually pigments. The dyes that I have talked about up until now actually dissolve in the ink solvents to yield a solution. Pigments, however, do not dissolve; they are discrete particles that must be dispersed in the ink. They yield a dispersion or suspension and not a solution.

The mechanics behind erasability are still not completely known, but I can give you a general description of why the ink erases. As the ink film is deposited on the paper by the rotating ball, the volatile hydrocarbon solvents flash off immediately; since the ink is very thick, it tends to sit on top of the paper and does not penetrate into it. The elastomer forms a film that the pigments are embedded in and can be easily removed from the paper by an ordinary eraser. After a day or two, however, the ink migrates down into the paper; then it becomes permanent and cannot be erased.

As I stated before, erasable ink is usually much more viscous than ordinary ball pen ink. Ball pen ink has a viscosity range of about 7,000 cps to 15,000 cps; erasable ink can be as high as 2,000,000 cps. When you compare this to water at 1 cps, you can see that it is quite viscous indeed.

The analytical procedures that have been covered before, infrared spectroscopy, ultraviolet visible spectroscopy, microscopic examination, thin layer chromatography, and vapor phase gas chromatography, can also be applied to erasable inks. We also use a rare earth date tag in our erasable ink so that the year of manufacture is more easily identified.

The primary work in our laboratories with writing instrument inks is directed toward goals other than those of the forensic laboratories. We are concerned primarily with developing improved formulations that will function better and be lower in cost than current inks. However, I hope that this discussion has been able to contribute something that may be of value to you, the forensic scientist.

DISCUSSION

Question: In assembling ball point pens, do you put a protective coating on the ball that makes it difficult to start writing?

Massey: We do not put any protective coating on the ball, but there is an open area around the rim and the ball that allows the solvent to dry out. Recently we have been getting some much better-starting inks. Some Japanese pens lately seem to have a protective coating over the ball. We have considered that approach.

Ryker: Can ink formulas be patented?

Massey: Yes, although it is pretty difficult to do nowadays. To be patentable, a product has to be really new, not just a modification of an existing product. Everything in the ink field now is pretty well known, and most of the changes to types of ink are not patentable because they are not really departures.

Patty: How large is a batch of ink, and can you pick up batch differences using instrumental techniques?

Massey: For ball pen inks, our normal batch runs 900 kg. We put half a gram of ink in a pen, so that figures out to about 1,800,000 pens per batch of ink. You probably could pick up differences from batch to batch depending on how long the ink stays in the kettle and on fluctuation in operating temperatures.

Prouty: How many major ink manufacturing firms are there in the United States?

Massey: There are approximately 12 major ink manufacturing firms in the United States.

Wagner: There is an ink in laundry markers that disappears after 48 hours or so. Do you know how that works?

Massey: Probably they use a dye that is easily oxidized by the air. Usually you can use an acid or something like that and bring the marks back.

Schlang: Could you elaborate on the dating techniques you use?

Massey: Date tags are rare earth—dysprosium, samarium, gadolinium, or something similar—usually in acetal acetate form. Every fiscal year the Department of Alcohol, Tobacco, and Firearms (ATF) tells us what rare earth we should use for the date tag during the next fiscal year and then we go out and buy some. We put a very low percentage of the rare earth into the ink, though—something on the order of 5 ppm. Then the ATF laboratory, using a neutron ac-

tivation process, takes a small little sample of the ink from the paper, analyzes it, and finds the rare-earth date tag in it.

Flynn: Do you know how successful ATF has been in soliciting the help of the other ink manufacturers in rare-earth dating of inks, and has any effort been made to get foreign manufacturers also to date tag their inks?

Massey: We have been dating our inks since 1968, and I believe some of the larger ink manufacturers—Papermate and Formu Labs, among others—are dating their inks. I have no idea whether foreign manufacturers have been contacted on this matter, but it would be a good idea. As I mentioned, more and more writing instruments are coming from Japan now, especially on the West Coast. And if the Japanese are not date-tagging their inks, the situation will worsen, I think.

Whitcomb: Would you have any details on the availability of European or Asian pens or inks in this country?

Massey: No. We get most of our information from

the Writing Instrument Manufacturers Association, but it has not been keeping any such records on imports. I have seen a lot more foreign products, particularly Japanese markers, in the stores in the last year or two than ever before. But I do not know how much of the market they are taking over or what their importation is doing to the market for American writing instruments. I would speculate that American manufacturers now supply about 70 percent of the market.

Question: I would like to know some of the brand names under which ink could be marketed in Canada.

Massey: We are a subsidiary of Scripto; anything that says Scripto or Everglide—another subsidiary of Scripto—has our ink in it. We do sell to other manufacturers of ball pens and markers, including A.T. Cross, but I do not know whether any of these sell their markers or writing instruments in Canada.

Question: Do you manufacture any ink for government contract work? I have often wondered who made those little black pens.

Massey: Yes, that is our ink.

DOCUMENT PRINTING INK COMPOSITION AND ANALYSIS AS RELATED TO THE PRINTING PROCESS USED

Robert W. Bassemir

Sun Chemical Corporation
Carlstadt, New Jersey

PRINTING PROCESSES

The three major printing processes used on most documents are letterpress, lithography and intaglio (engraved plate).

These three processes have distinct applications in document printing and are chosen because of the nature of the printing process itself as well as security implications, as in the case of intaglio.

An examination of the characteristics of each process should provide insight into the reason each process is used.

Letterpress

This process is technically known as typographic because it uses raised type and images to transfer ink to a substrate. This was the original printing process and used carved wooden blocks as the printing plate. It is characterized by moderately high impression pressures in order to achieve good contact with substrates such as paper, which has a generally irregular surface. Ink is distributed in a thin film on a roller system, rolled on the raised printing image areas, and then transferred to the substrate using an impression roller to achieve the desired contact pressure.

Letterpress in documents is principally used for serial numbering or printing of identification numbers. The numbering elements are made from raised metal type wheels and can be easily mechanically indexed during the printing process.

Lithography

This process is technically known as a planographic process because it uses a flat surface printing plate. The image areas are chemically differentiated from the nonimage areas. That is, they are oleophilic and ink receptive, while the nonimage areas are hydrophilic or receptive to water solutions such as the dampening solution used to keep these areas free from ink. In practice, the plate is first dampened with an aqueous solution of buffer salts and protective colloids to completely wet the nonimaged areas. A roller covered with ink is immediately passed over the plate under moderate pressure, which transfers ink only to highly oleophilic image areas.

In direct lithography, the plate is then pressed directly against the substrate to transfer ink in the image areas. The most popular use of lithography, however, is the

offset process. The inked plate is pressed against a cylinder covered with a thin rubber blanket, transferring the image to the blanket. The blanket cylinder is then pressed with moderate pressure against the substrate, transferring the inked image to the paper. This offset process has several advantages, mainly its usefulness in printing rough and uneven substrates such as uncoated paper, which is frequently used for documents. The rubber blanket is resilient enough to contact the uneven areas on the paper surface, producing a more uniform image area than letterpress printing.

Intaglio

This process is commonly known as copper or steel engraved plate printing because it uses recessed image areas. In document printing, these may be hand or mechanically engraved directly into the surface of the metal plate. In operation, the recessed images are filled with ink and the surface of the plate is wiped clean. This is accomplished with special elastomeric inking rollers or fabric or paper rolls. The recesses are the only areas on the plate containing any ink. The substrate, which may be predampened paper, is pressed against the plate under extremely high pressures. This forces the substrate down into the recesses in the plate, allowing it to contact the ink. On separation, a good portion of the ink in the recesses is transferred to the paper. Obviously, this process is slower and more complex than the other two and is used mainly for high-security printing of currency, bonds, etc.

THE MICROSCOPIC IDENTIFICATION OF PRINTS

Each printing process produces a print on paper that is usually quite characteristic, and may be used to identify the printing process. An examination of each of the three major processes using a high resolution microscope with magnifications from 10x to 200x will usually tentatively identify the printing method. The type of lighting is important and usually several different types will be employed on the same specimen. Incident illumination is usually used rather than transmitted light, although the latter may be occasionally revealing. In addition to normal incident light, grazing illumination and vertical illumination (epi) are also useful in observing whether a surface is raised or depressed.



Figure 1. Letterpress print on currency magnified 37.5x. Note thickened ink deposit at edges.

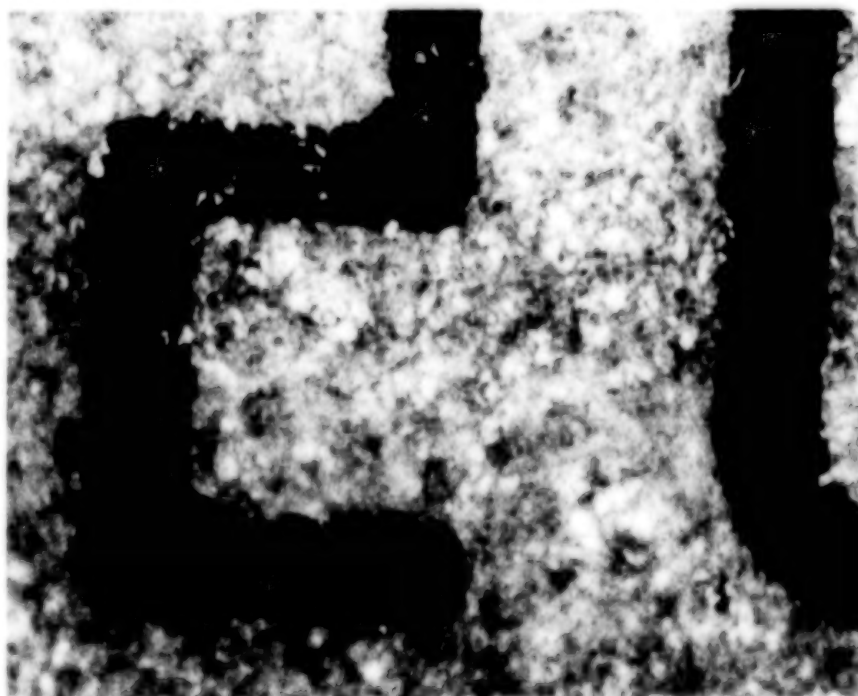


Figure 2. Letterpress print on check with magnetic ink magnified 37.5x.

Letterpress

In letterpress the images, particularly the type, have non-uniform density from edge to edge. They generally have squashed edges because of the pressure used in the printing process and the raised type, which combine to force excess ink to the edge of each image. This produces the typical letterpress appearance (Figures 1 and 2).

In addition, there may be a number of small skips or areas that did not print because of low spots in the paper surface. Letterpress generally will not fill in these low spots as readily as other printing processes.

The paper fibers in uncoated stock are usually squashed flat and free of very dense ink deposits. The image areas may be slightly depressed. Both effects are caused by the pressure of the raised type on the paper.

Ink film thickness in letterpress is generally from 2 to 4 mm.

Offset Lithography

With this type of printing process the image has quite uniform density from edge to edge. Type has smooth and relatively unbroken edges and the paper fibers within the image are generally covered with ink (Figure 3).

There will be very few skips even on rough paper surfaces, because of the resilience of the rubber blanket.

There may be some tiny white areas evenly distributed within the image. These are caused by surface water droplets on the inked image, which cause the ink to fail in transferring to the paper (Figure 4).

Ink film thickness in offset lithography is generally from 1 mm to 1.5 mm.

Intaglio

In this process, the images have thick ink deposits from 10 mm to 200 mm and may be convex in appearance. Some of the type images will have ragged edges and the ink surface may appear somewhat uneven (see Figures 5 and 6).

The paper surface is usually embossed in the image areas, thus enhancing the convex appearance of the type. The edge of these images may show a few filaments from the stringing effect of the ink as it splits.

Grazing illumination is usually helpful in identifying this printing process because it gives the image a three-dimensional raised appearance.

The use of scanning electron microscopy (SEM) may be indicated for some types of printing that are difficult to observe with optical microscopy. It is also helpful to have an energy dispersive X-ray attachment (EDAX) for the SEM. In this instance, it is useful to get element identifications of the ink ingredients used. This is particularly the case when intaglio inks, having large quantities of inorganic fillers, are present on the document (Figure 7).



Figure 3. Offset litho print on check magnified 37.5x.



Figure 4. Offset litho print on driver's license magnified 37.5x.

INK FORMULATION

Two classes of formulations are likely to be encountered in document inks, regardless of the printing process used. These are fully oxidizing and quickset oxidizing. In the case of offset lithography, it is also possible to encounter radiation-curing inks, specifically ultraviolet curing.



Figure 5. Intaglio print on state bond magnified 37.5x. Note raised ink areas and embossing on substrate.

The following formulations are general compositions giving generic descriptions of the raw materials, since there are many manufacturers making a variety of proprietary products, particularly in the ink vehicle area.



Figure 6. Intaglio ink on bond magnified 100x (SEM photograph). Note thick ink deposit and convex image.

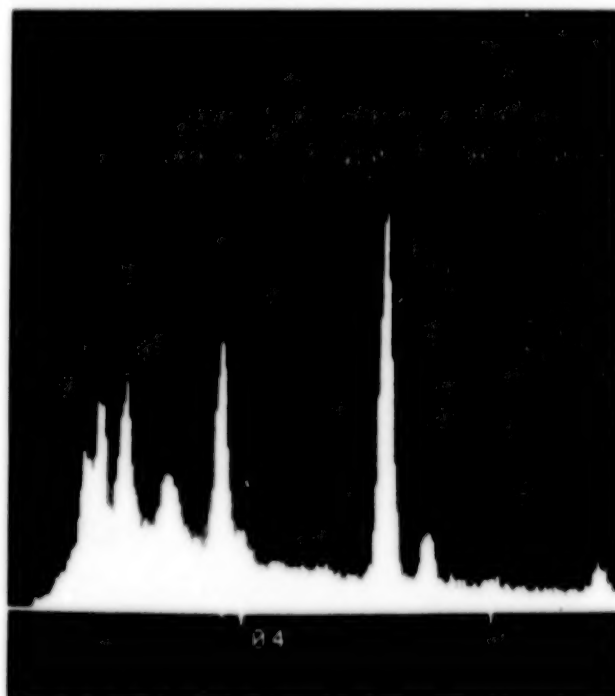


Figure 7. Energy dispersive X-ray pattern of intaglio bond ink. Elements shown are iron, calcium, silicon and aluminum.

LETTERPRESS

<u>Ingredient</u>	<u>Full Oxidizing</u>	<u>Quickset</u>
Pigment (carbon black or organic color)	10-12%	10-12%
Vehicle:		
Linseed oil alkyd	75-80%	5-15%
Rosin ester	5-10%	45-50%
Hydrocarbon resin	0%	5-10%
Hydrocarbon oil (Kerosene fraction)	0-1%	12-15%
Reducer (solvent)	0-1%	1-3%
Wax (polyethylene)	1%	1%
Drier (cobalt and/or manganese soaps)	1%	0-0.5%
Antioxidant (BHT)	0.1%	0%

OFFSET LITHOGRAPHY

<u>Ingredient</u>	<u>Full Oxidizing</u>	<u>Quickset</u>
Pigment (carbon black or organic color)	13-16%	13-16%
Vehicle:		
Linseed oil alkyd	55-65%	5-15%
Phenolic rosin ester	10-20%	45-50%
Hydrocarbon resin	0%	5-10%
Hydrocarbon oil (kerosene fraction)	0-1%	12-15%
Reducer (solvent)	0-1%	1-2%
Wax (polyethylene)	1%	1%

Drier (cobalt and/or manganese soap)	1%	0-0.5%
Antioxidant (BHT)	0.1%	0%

Ingredient	Ultraviolet Curing	
Pigment (carbon black or organic color)	10-15%	
Vehicle:		
Acrylic oligomers	20-35%	
Acrylic monomers	35-50%	
Photoinitiator (aromatic ketones, benzoin ethers, etc.)	3-12%	
Thermal inhibitors (MEHQ, etc.)	500 ppm-2000 ppm	
Wax	1%	

INTAGLIO

Ingredient	Full Oxidizing
Colored organic pigments	0-15%
Colored inorganic pigments (metal oxides, etc.)	0-40%
Filler pigments (clay, talc, TiO ₂ or other inorganic whites)	25-60%
Oleo-resinous varnishes (cooks of tung oil and/or linseed oil with pure phenolic and/or maleic resins)	20-30%
Driers (cobalt and/or manganese soaps)	1-3%
Antioxidants (BHT and/or eugenol)	0.1-1.0%

INK VEHICLE CHEMISTRY

Molecular Structure of Resins

As can be seen from the formulations in the previous section, the major types of resin used in document inks are usually based on rosin chemistry or vegetable drying oils.

Rosin-based resins use this natural material, which is obtained from one of three sources. Gum rosin and wood rosin are derived directly from trees or stumps. However, the most commonly used rosin today is tall oil rosin, a by-product of the papermaking processes. Because of economics, tall oil rosin has almost completely supplanted wood and gum rosins.

Chemically, rosin is a complex ring structure having a pendant COOH group and two double bonds. It is commonly modified with a number of chemicals

to produce synthetic resins. These include maleic anhydride, various phenol derivatives and polyols. The reaction of the rosin with these materials increases its molecular weight and melting point. In addition, ink films made with modified rosins have superior functional properties.

Other important resins used in document inks are oil-modified alkyds. These are really polyester resins, usually made with phthalic or isophthalic anhydride, various polyols, such as glycerol or trimethylol propane and modified with a vegetable drying oil. The most common drying oil is linseed oil, which is a triglyceride of various C-18 fatty acids. These acids have conjugated or nonconjugated unsaturation and are prone to oxidation at room temperature in the presence of air and metallic catalysts. Oil-modified alkyd resins, when fully oxidized, produce tough, flexible and chemically resistant films that are desirable for document printing.

Oleo-resinous varnishes are another class of ink vehicle used in currency inks. They are composed of drying oils such as linseed oil and/or China wood oil (Tung oil) heated together at high temperature with phenolic and/or maleic-modified resin. Tung oil is a triglyceride of eleostearic acid, which has conjugated unsaturation in its backbone and produces very tough films when oxidized.

The other class of resin used is a synthetic hydrocarbon resin made by polymerization of hydrocarbon streams from oil refineries. These resins are generally very soluble in ink solvents and help balance the solubility of ink vehicles for the quickset type of ink.

In ultraviolet-curing inks, mention is made of acrylic monomers and oligomers. These are generally acrylate esters or polyesters and cure to a dry film through free radical polymerization. The free radicals are created by ultraviolet irradiation of photoinitiators (for example, aromatic ketone type). These initiate a chain reaction in the acrylic resins, causing an instantaneous increase in molecular weight, producing the dried ink film (Pappas).

Molecular Weight Distribution

If the resins described above are run on a gel permeation chromatograph (GPC), the molecular weight distribution can be obtained. This helps to characterize these materials as long as they are still in a soluble form. Figures 8 through 10 show the GPC curves and molecular weight distribution of some of the typical resins described above. The molecular weight of most of the resins used in these types of inks may be seen to be quite low when compared to other types of coating resins and vehicles. This is necessitated by the nature of the printing machinery and the constraints that this hardware imposes on the viscosity and solvents used in ink formulation. A list of average molecular weight for several of the typical resins discussed above is given in Table 1 (Carlick 1984).

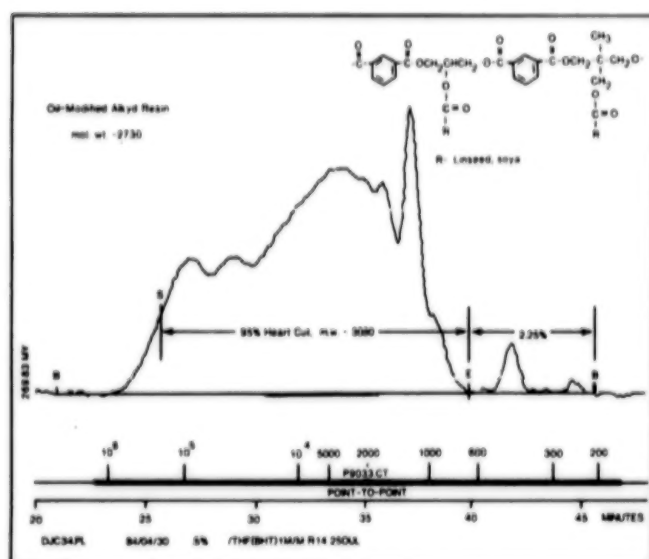


Figure 8. Gel permeation chromatograph of Alkyd resin (linseed oil and soya oil modified).

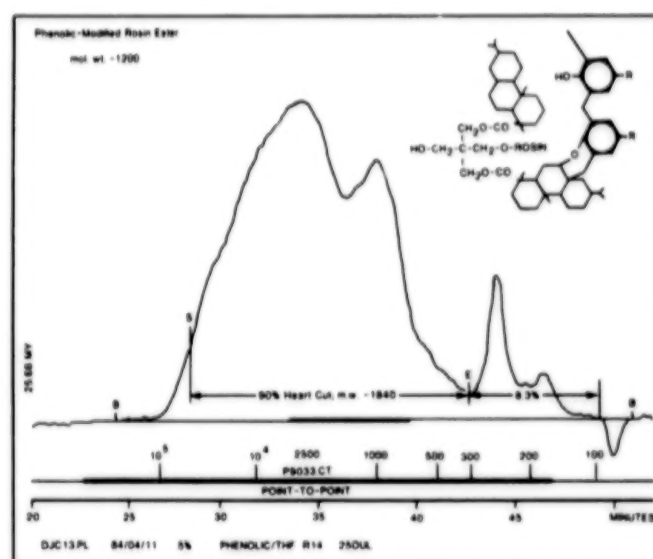


Figure 9. Gel permeation chromatograph of phenolic rosin ester.

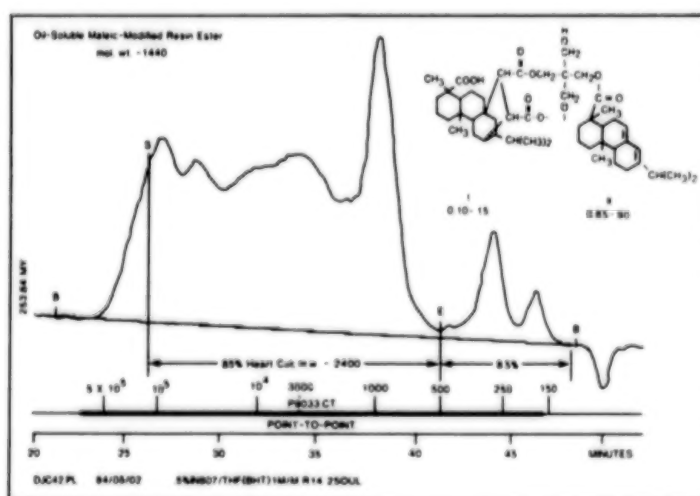


Figure 10. Gel permeation chromatograph of maleic rosin ester.

Table 1. MOLECULAR WEIGHT OF INK RESINS

RESIN TYPE	AVER.MOL.WT.	AV.MOL.WT.(HEART CUT)
ALKYDS	2730	3080
MALEIC-ROSIN ESTER	1440	2400
PHENOL-ROSIN ESTER	1200	1840
NON-FUNCT.H/C	500	550
FUNCTIONAL H/C	710	800

Table 2. PERCENT SOLIDS AND VISCOSITY OF INK RESINS

Resin Type	Percent Solids	Solvent Type	Viscosity-Poises @ 25°C	Printing Process
Alkyd	600-100	Magie	4-500	Litho
Linseed	80-100	Magie	0.5-250	Litho
Maleic/Rosin	45-70	Magie	50-500	Litho
Hydrocarbon	50-70	Magie	50-400	Litho
U.V. Oligomers	98-100	None	20-1000	Litho

Solubility Characteristics

The solubility of ink resins is extremely important since very few solvents can be used in ink formulations because of potential problems occurring when solvents interact with rubber rollers, plates, blankets or other parts of the printing equipment. The most commonly used solvent in document inks is a most aliphatic hydrocarbon with a relatively narrow boiling range and a low-solubility characteristic (Kauri-butanol value less than 35). Table 2 gives the solubility and viscosity of solutions of resins in this type of solvent (magie oil). The viscosity of printing inks is exceedingly important since it must be controlled within relatively narrow ranges for the ink to print properly in the very thin films the press requires. Note that the ultraviolet vehicles contain no solvent and must be adjusted to the proper viscosities by blending acrylic monomers and oligomers.

INK COLORANTS

Pigments

Pigments used in printing inks are generally insoluble in the ink vehicles used and may be classified as organic or inorganic. The inorganic pigments most commonly used are:

Carbon black	Talc
Iron oxides	Silica
Other metal oxides	Alumina
Clay	Mineral wiping aids

In general, inorganic oxide colors are used mainly in currency inks because of their permanence and resistance to bleeding and chemical attack. Intaglio inks re-

quire colorless wiping aids and mineral fillers to produce the short body and high viscosity required to print on the presses used in this process.

The organic colored pigments number in the hundreds and are widely used in letterpress and lithographic inks. The classes and types of these, along with their molecular structure resistance properties and color curves, are listed in the NPIRI Raw Materials Handbook.

Dyes

While dyes, which are soluble colorants, are used in a number of printing inks, their use in document inks is rare because they tend to bleed in common solvents such as water and alcohol. The exception to this is their use in the formulation of certain security inks used for background printing of checks and similar documents. These inks use dyes and water soluble vehicles to prevent alteration of the written figures with solvents or ink eradicators. These materials would irreversibly change the background printing, producing an obvious change in color and uniformity of the check surface.

INK ADDITIVES

Printing inks may contain a number of other ingredients in small percentages to significantly change or modify the film properties. In fact, it is often said that the difference between a good ink and a poor one can be the nature and amount of the additives used.

The most important additive for oxidizing inks, which are commonly used for printing documents, is the chemical drier. These additives are essential to catalyze the absorption of oxygen by the drying oils, causing their polymerization. They are generally

organic acid salts or soaps of the following metal ions, used alone or in combinations:

Cobalt	Calcium
Manganese	Cerium
Zinc	Zirconium

Another important class of additive is waxes and slip agents, which control the rub and scuff resistance of printed ink films. The most common types are polyethylene (medium and high molecular weight), microcrystalline hydrocarbon waxes and Teflon powders. These materials are generally present in amounts of about 1% to 3% depending on the type of ink and the nature of the substrate on which it is printed.

Antioxidants (Inhibitors)

The presence of drying oils in oxidizing inks creates a tendency for these inks to form tough skins on the top of ink cans and containers, and may also cause skinning in the fountain of a press over time. To prevent this, antioxidants are used in very small percentages, ranging from 500 ppm to as high as 0.2%. The representative compounds usually used are:

Butyl hydroxy toluene
Butyl hydroxy anisole
Hydroquinone and its ethers
Eugenol (oil of cloves)

ANALYTICAL TECHNIQUES USED FOR PRINTING INKS

The analytical techniques used in the printing ink industry are most often applied to samples of wet ink, but some of them may be applicable to dried ink films depending on the nature of the formulation and the substrate on which it is printed.

Most ink analyses attempt to separate the vehicle, additives and colorant and then individually identify each of these substituents. Instrumental techniques are extremely common, particularly when the dry ink films are involved because of their high sensitivity and the small amount of material available for analysis.

Separation of the ink film is usually attempted with strong solvents such as acetone, MEK, ethyl acetate, toluene, chloroform, tetrahydrofuran, acetonitrile, dimethyl formamide and dimethyl sulfoxide. Many times the use of paper chromatography on the dried

ink film can effect a partial separation of the ingredients using one or more of the above solvents. At this point, instrumental techniques are indispensable for characterizing or identifying the separated ingredients.

The most important instruments are listed by frequency of use:

Infrared spectroscopy and Fourier transform infrared-ATR
Infrared reflectance and transmittance as required
Gas chromatography
Mass spectroscopy and GC/MS
Ultraviolet spectroscopy
Visible spectroscopy
Pyrolysis gas chromatography and mass spectroscopy
Direct probe mass spectroscopy
Atomic absorption and inductively coupled plasma AA
Energy dispersive X-ray and scanning electron microscopy
Surface analyses-auger, ESCA, SIMS, etc.

REFERENCES

- Carlick, D. (1984).* Physical chemical similarities among typical printing ink resins, American Ink Maker, December.
NPIRI Raw Materials Handbook, Vol. 4—Pigments, National Printing Ink Research Institute, Lehigh University, Bethlehem, Pa.

SUGGESTED READINGS

- The Printing Ink Handbook, Printing Manufacturers, Harrison, N.Y. 10528.
The Printing Ink Manual, 1979 Northwood Books, London, England.
Inks for security printing, American Ink Maker, August 1979.
Color change inks, American Ink Maker, November 1983.
Helping beat the counterfeiter, Lithoweb, January 1985.
Pappas, S. P. (ed.). UV Curing: Science and Technology, Technology Marketing Corporation.

OVERVIEW OF TYPEWRITER RIBBONS AND INKS

Donald L. Elbert

International Business Machines Corporation
Lexington, Kentucky

This paper presents an overview of the different families of typewriter ribbons and inks and some of their applications. Included are inks for impact, thermal and jet printer technologies.

Fabric Ribbons

Fabric ribbon is one of the oldest types of typewriter ribbons. In this type of ribbon, the substrate or carrier is a woven fabric. By using a special inking machine, liquid ink, usually of a relatively low viscosity, is applied to the fabric. Originally, the fabric was cotton but today's ribbons are made of nylon, the preferred material, because of its impact strength. Use of fabric ribbons in typewriters has been declining because fabric ribbons do not give letter-quality print. However, fabric ribbons are used extensively for non-letter-quality printers such as high-speed computer printouts and wire matrix printers.

The advantage of a fabric ribbon is low cost per character since the same spot on the ribbon may be struck many times before the ink is depleted. This results from the capillary flow from unused portions of the ribbon to the used portion. The major disadvantages are non-letter-quality print and a declining level of print quality as the ribbon is used.

Bicolor (red and black) fabric ribbons have been available for many years. Recently, four-color ribbons were introduced. These are typically cyan, magenta, yellow and black, but can be red, blue, green and black. These ribbons have barrier stripes to prevent mixing of the inks. The four color ribbons are used primarily on printers attached to color displays.

The typical black fabric ribbon ink is composed of carbon black, dyes (nigrosine/methyl violet), fatty acids and high-boiling esters.

The ink must be nonevaporating and nonreactive. It also must provide optimum viscosity for print quality and life, high color strength and archival properties.

Carbon black and dyes are used to obtain the required color strength and proper color. Fatty acids and high-boiling esters are the vehicles that carry the pigment and dye to the paper. These materials must be nonevaporating and nonreactive because fabric ribbons are exposed to air and light for long periods of time. The ink viscosity is controlled by selection of the percentages of each of the ingredients.

If the ink viscosity is too high or the ink is thixotropic, the capillary flow from unused to used portions of the ribbon will not occur and life will be shortened. A high ink viscosity will also cause light print. On the other hand, if the ink viscosity is too low, excess ink will transfer to the paper resulting in poor

print quality and shorter life. Since only a very small amount of ink is transferred to the paper, high color strength is required to obtain good print quality. Finally, print on the paper must be permanent. Fabric ribbon inks are permanent because the pigment, carbon black, is resistant to light, water, bleach, erasing, etc., and the ink soaks into the paper.

Color inks may be made by using other pigments and dyes. The ink vehicles are the same as black inks. Archival properties depend on the particular pigments and dyes used to obtain the desired colors.

Single-Use Ribbons

The second major family of typewriter ribbons is the single-use film ribbons, composed of a thin substrate coated with a thin film of solid ink. The primary advantage of this type of ribbon is letter-quality printing on a wide range of papers. Correctable film ribbons fall into this family and are the most pervasive in the typewriter market today. The main disadvantage for single-use film ribbons is cost per character. As a result, film ribbons are not widely used on printers.

The earliest film ribbons were carbon paper slit to ribbon width. The disadvantages of paper ribbons were breaking and fuzzy print. About 1960, a significant breakthrough was made with the substitution of extruded polyethylene film for paper, solving the breaking problem and dramatically improving print quality. In 1973, the next major advance occurred with the introduction of the correctable film ribbon, which had a special ink making keyboard correction possible.

Inks for film ribbons fall into two basic types: non-correcting and correcting. The composition for each is as follows:

<u>Noncorrecting</u>	<u>Correcting</u>
Pigment	Pigment
Dye	Resins
Wax	Oils
Oils	

Noncorrecting inks based on waxes are applied by hot melt coaters. Correcting inks require higher molecular weight resins to obtain sufficient strength for correction and are made by coating a roll coater with solvent and passing it through a hot air dryer.

Noncorrecting ribbons have soft inks that soak into the paper, making them difficult to erase. Carbon black is typically used as the pigment for black ribbons and renders the print on paper resistant to water, light, bleach, etc.

On the other hand, correcting inks are formulated to remain on the paper surface rather than penetrating into the paper fibers, so that they may be lifted from the paper through contact with a second ribbon, normally some type of pressure-sensitive, adhesive tape. Although correcting ribbon ink stays on the paper surface, it does have a degree of permanence since the impact of the typewriter embosses the paper surface and can be detected. Correctable ribbons are not recommended for permanent documents such as wills or negotiable instruments such as checks.

Multistrike Ribbons

The third family of ribbons, multistrike, falls between fabric and single-use ribbons. Multistrike ribbons consist of a thin plastic substrate, such as nylon or polyester, that is coated with a polymer having liquid ink dispersed throughout as a second incompatible phase. When this ribbon is struck and compressed during typing, the ink is squeezed out onto the paper. A cross-section of the ribbon structure is shown in Figure 1.

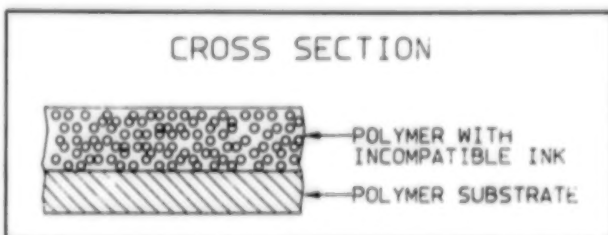


Figure 1. Tech III ribbon.

Like the fabric ribbons, the multistrike ribbons may be struck several times in the same spot before the ink is depleted. Since there is no bulky fabric, this type of ribbon gives print quality approaching but not equaling single-use ribbons. Since a liquid ink is used, the print is not correctable other than by cover-up. Multistrike ribbons are used in limited amounts for typewriters but are used extensively for letter-quality printers where more favorable cost per character becomes an advantage.

Inks for multistrike ribbons are similar to fabric ribbons. The ink is permanent since it soaks into the paper and has carbon black to provide light, water and bleach resistance.

Thermal Ribbons

The fourth family of ribbons is thermal. One version, resistive ribbon thermal transfer, was introduced commercially in 1984 for both typewriters and printers. In this newest nonimpact technology, heat is used to melt the ink, transferring it to the paper. The ribbon consists of a substrate, an aluminum ground layer and ink. A cross-section of the ribbon structure is shown in Figure 2.

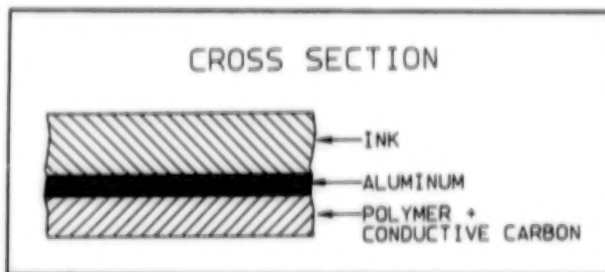


Figure 2. Resistive thermal ribbon.

A current is passed through the polymer-carbon substrate by contact with an electrode. As the current passes through the substrate, it generates heat, melting the ink at that point. The aluminum layer conducts the current to ground.

The ink, a solid, consists of polymers and carbon black. Since the ribbon is correctable, the print is not considered permanent. However, it is resistant to light, bleach, etc., because of the carbon black. Unique to this technology is the use of the ribbon itself as the correction medium.

A much older type of nonimpact thermal ribbon is also available. Known as thermal transfer, this ribbon consists of a thin polyester substrate which is coated with a hot melt ink similar to noncorrecting hot melt inks. The cross-section of the thermal ribbon structure is shown in Figure 3.

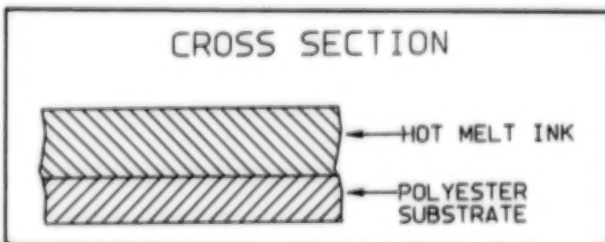


Figure 3. Thermal ribbon.

In this case, the heat is generated by having the resistance in the print head rather than the ribbon. At this time, this technology has been used only on printers. Archival properties are similar to other hot melt inks.

Ink Jet Printers

Although they are not a typewriter technology, I would like to briefly address inks used for ink jet printers. This is another nonimpact method of printing that may become widespread in the future.

The two types of ink jet printers are: (1) those that print by putting a charge on the drop that is to be printed and recirculating the uncharged drops (electrostatic), and (2) those that print by forming only drops to be printed (drop on demand).

The inks are similar in that both use dyes rather than pigments. The compositions of the two types of inks

are:

<u>Electrostatic</u>	<u>Drop on demand</u>
Water-soluble dye	Glycol-soluble dye
Humectants	Glycols
Water	Other high-boiling solvents

Dyes are used because pigments clog the small nozzles (1 to 2 mils). In electrostatic technology, the ink must be capable of accepting a charge, which determines that water must be used as the solvent. In drop on demand, there is no charge involved so other

solvents such as glycols may be used. Because of their lower vapor pressure, the glycols do not evaporate, improving the liability of this type of ink. These inks are difficult to erase because they soak into the paper. However, since dyes rather than pigments are used, the print is susceptible to change from bleach and light.

This is a brief overview of the various families of ribbons and inks used in impact, thermal and jet printer technologies. I hope this information has increased your understanding of some types of ribbons and inks used in the office environment and will be valuable to you in your different work activities.

BLANK PAGE

TYPEWRITER MANUFACTURING

Donald W. Johns

International Business Machines Corporation
Lexington, Kentucky

I have been asked to discuss typewriter manufacturing. I realize how the various mechanical movements of the machine can affect how the type appears on paper, especially with age and wear. However, information that I have that would be of significance to questioned documents would be in the area of type manufacture and type design, since that is the area of my responsibility. I will give a brief history of the typewriter, touch-on type elements and wheels as print mechanisms and will conclude with discussing electronic fonts, our latest technology. This is the area where I have done most graphic designs. Although there are other typography media, such as ink jet, the element and wheel are the most widely used for typewriters.

HISTORY OF THE TYPEWRITER

It seems that to qualify as a typewriter, a contrivance must meet two basic requirements. It must be mechanical and must be capable of printing characters or groups of characters in succession according to the operator's choice. One of the earliest records of such a machine was a patent by Henry Mill, a British engineer, in 1714. There were many others, but there was no real production until about 1850. One of these machines was Foucauld's Clavier Imprinter, manufactured in France in the 1850s. One of the first to be called an electric was Devincenzi's of 1854. Thomas Edison had an electric using a printing wheel in 1872. Do not confuse this with the present day wheel. It was more cylindrical, with similar specifications as the Selectric element that IBM would announce about 100 years later. So the principle of the typing sphere has been around since the earliest models. Also, differential spacing attempts were made and then mostly abandoned around the turn of the century. About 40 years later, IBM reintroduced this as proportional spacing.

IBM's history of typewriters dates back to July 21, 1933, when they purchased Electronic Typewriters, Inc., as well as their Rochester, New York, plant and manufacturing facilities. The typebar Model A was first, followed by Models B, C and D. The Selectric principle was introduced in the 1960s with many advancements in between, and the latest in 1984—the Quietwriter.

I like to think of IBM as being a pioneer in electric typewriter development with unquestioned excellence in typography, evidenced, in many cases, by identical duplication by our competitors.

The end product of the typewriter is communication.

Type is a medium. It is the message on paper. Just as a good speaker must speak clearly, make his or her point and get the message across, typography should do the same on paper. No matter what other technical advancement, capabilities or enhancements are on the machine, the quality of the printed result is still important to the customer. Type design must never be underestimated!

ELEMENT MANUFACTURE

The material used for molding elements was chosen because of its molding stability, critical dimensions and endurance. Character fill is a prevalent problem in element manufacture. A number of things affect this, such as temperature, cycle time and moisture. Holding the writing line is one of the critical dimension problems in this process. Therefore, close and frequent checks must be made of all these factors to maintain the best print quality.

If there is an indentation or protrusion on the character or anywhere on the element, the nickel plating will not necessarily fill in or even out. In some cases it will even be magnified.

The tamper-proof cylindrical shipping and storage containers for elements, introduced in recent years, provide protection in storage. Even with the most stringent quality control in type element manufacturing, unique dimensional differences and possible flaws, although acceptable for the printed page, may be useful information for document examiners.

The typebar machines (Model D and back) would have over and under printing if not designed to specifications. In elements, not only over and under, but also side printing has to be taken into account. This becomes more critical when increasing from 88 characters to 96. Two more slides (columns of characters) were added to the area, thus crowding the characters that much closer.

WHEEL MANUFACTURE

The manufacture of print wheels involves basically the same problems as elements having the same critical tolerance constraints.

Neither side printing nor over and under printing is a problem since each petal is moved forward to the platen individually.

Horizontal alignment in the molding process is critical, more so than with the element (character must

be aligned with the detent on the back of the petal).

There is coded information on elements and wheels for identification and tracing should there ever be a problem.

Of course, ribbons and paper have everything to do with print quality. The correct ribbons and paper are always recommended for the particular machine or document purpose.

Molding processes are automated. In fact, all manufacturing concerning type is automated.

QUIETWRITER — ELECTRONIC FONTS

The Quietwriter technology lives up to its name with noiseless typing or printing because it is nonimpact. It is a typewriter with an electronic print mechanism. It is a matrix design with the printed image accomplished by thermal transfer. An erase feature has also been accomplished with this. It has an expanded feature (double-wide characters) for headings and titles. It prints 40 to 60 characters per second and has a storage capacity of 7,000 characters. There are 29 typestyles available.

The font modules are interchangeable much like video game cartridges, only easier and on a smaller scale.

As you might guess this technology requires its own special ribbon.

The question may arise as to the difference in appearance when comparing this printing with the wheel or element. The Selectric is more or less the standard for graphics, and although this design is as close to it as possible for each typestyle, the difference lies in the dot matrix pattern versus an engraved pattern.

MARKETING TRENDS

Anything said here with respect to trends would deal either directly or indirectly with graphics.

There is a need for more characters on a page, which means you will see more small typestyles (more characters per inch), such as 15 pitch, and smaller point sizes. It also seems that the speed for printing these kinds of characters is ever increasing. However, there still appears to be a very definite need for the character to have an excellent appearance. Both are continued goals for expanded effort.

THE CLASSIFICATION OF PHOTOCOPY MACHINES FROM PHYSICAL CHARACTERISTICS

Elizabeth L. James

FBI Laboratory
Washington, D.C.

The identification and classification of photocopies present special problems to the document examiner (Lile and Blair 1976; Kelly 1983). The following discussion will deal with the identification of office copy machines by using their class characteristics through the use of a computer. If the machine cannot be identified by its class characteristics, there is little the document examiner can do to aid the investigator in locating suspect machines. Once the suspect machine has been located, a comparison can then be made between the questioned and known specimens using any unique markings that may appear on the evidence.

Photocopy machines do have class characteristics, and these class characteristics can act as a method of searching a file for the machines that most closely resemble the one used to produce the evidence. The vehicles for this search are DB MASTER, a database management package and an Apple II computer.

There are 10 class characteristics that the FBI Laboratory uses to classify photocopies. The majority of these characteristics are searched by a yes or no response. This approach was chosen because of the quickness of the response time.

PAPER TYPE

Paper type is the first class characteristic to be considered. The two types of paper considered are plain or coated. Plain paper is standard bond of a minimum weight specified by the photocopier manufacturer. Coated paper is treated with a metal oxide, typically zinc oxide, to create a charge-sensitive surface. A metal object such as a coin will leave a dark mark when rubbed against coated paper.

TONER TYPE

Type of toner is divided into two categories—liquid and dry. This determination can be made by observing the photocopy under slight magnification (approximately 30x). If discrete particles of toner can be seen, it is dry toner. Dry toner has a raised, glossy appearance on the paper and can be scraped off the page with a scalpel. Liquid toner, in contrast, appears to have dyed the individual paper fibers. The Landa Process, developed by Benny Landa for Savin, can be distinguished from other liquid toners by appearance at magnification of 100x. The color of the toner is much darker and has the appearance of printer's ink. The older

Savin machines have been retrofitted to accept this new technology. Canon and Savin are the most common plain paper, liquid toner machines in the domestic market.

TONER APPLICATION

The toner applications of concern here are either the magnetic brush or cascading development procedure. This class characteristic pertains only to dry toner photocopy machines. This choice is subtle and may not be apparent in simple text reproduction. If the photocopy has a large black area reproduced (larger than 1/2 in x 1/2 in) and this area is significantly lighter in the center than it is on the edges, this is indicative of cascade toner development. The reason for this is the point charge effect in electrostatics. In order to be most stable, an electrostatic charge will migrate to the edges and points where its charge density will be greatest. This occurs instantaneously after the electrostatic charge is placed on the drum and the copy is focused onto it. When toner is cascaded onto the drum, it causes mechanical abrasion in the already charge-weakened areas and the toner adheres poorly to this area. If the toner is more gently applied by a magnetic brush, this effect is minimized.

REDUCTION

Another feature of the classification process is reduction. This is a simple choice between reduction or no reduction. Most photocopy machines, because they use an optical system, reduce or enlarge the copy somewhat. The reduction addressed in this characteristic is the obvious attempt by the manufacturer to reduce copy size significantly.

ENLARGEMENT

This class characteristic is divided into a choice of enlargement or no enlargement. The enlargement addressed is the obvious attempt by the manufacturer to enlarge the copy size significantly.

The database also contains the actual reduction and enlargement ratios that are available for these photocopy machines. Care must be exercised because a document may be reduced or enlarged numerous times.

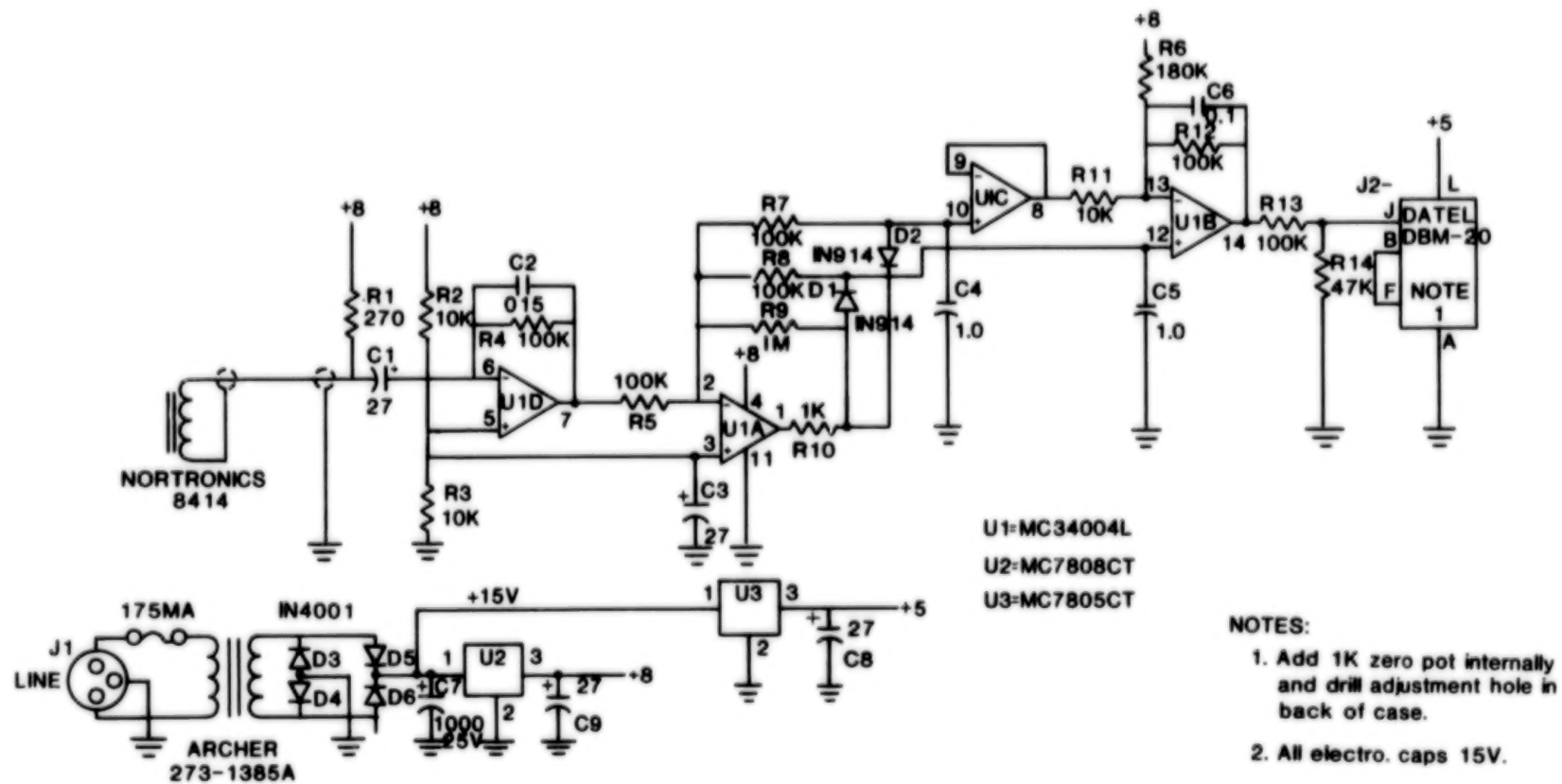


Figure 1. Schematic of magnetic ink detector.



Figure 2. Savin 770.

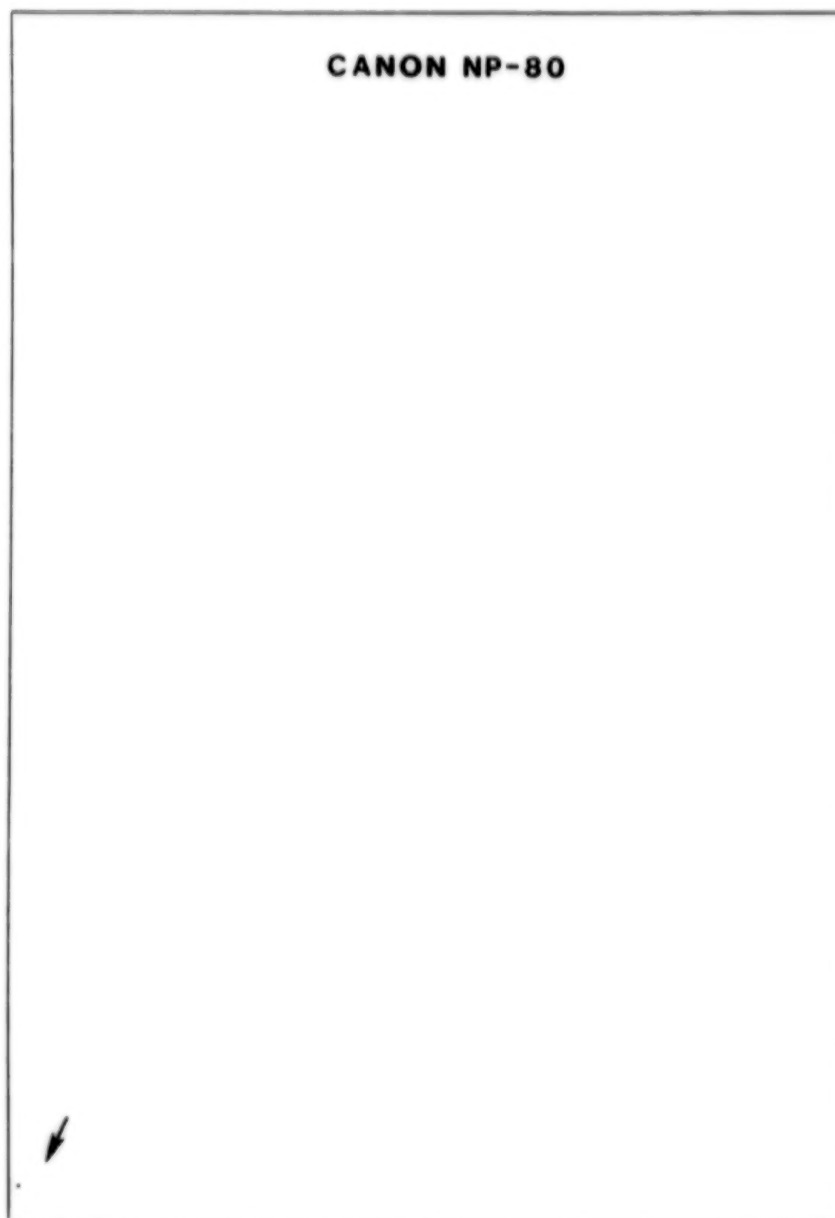


Figure 3. Canon NP 80.

MAGNETIC

Photocopy machines use a monocomponent or dual-component toner. These plain paper, dry toner machines may or may not be magnetic. Monocomponent toners incorporate the properties of toner and developer in a single particle (Falls 1983). These particles are larger than those found in dual-component toners (Falls 1983). The monocomponent toner is highly magnetic because the two substances (toner and developer) are combined for the transfer to the paper. Dual-component toners, on the other hand, mix the small toner particles and the large developer particles at the time of application on the surface of the photoconductor (Unley 1985). Dual-component dry toner machines provide a better contrast quality because of the small-size particles. Monocomponent dry toner machines, on the other hand, are less expensive and easier to maintain because storage, metering and recycling of the developer is eliminated (Falls 1983). To determine the degree of magnetism of a toner, the Magnetic Ink Detector is used. Figure 1 is a schematic of this instrument which detects the degree of magnetism of the toner. A simpler but much less sensitive method is to rub a magnet across the photocopy and to place a magnetic viewer in contact with it. If the magnetic viewer visualizes the photocopy, the toner is magnetic. Before the development of the Magnetic Ink Detector, it was thought that only monocomponent toners were magnetic. It has now been established that some dual-component toners have a low level of magnetism. This is probably caused by the slight retention of developer particles. Using this class characteristic as a criteria in the classification of a piece of evidence greatly reduces the number of possible manufacturers.

PAPER SUPPLY

The paper supply category is divided into sheet-fed or roll-fed. If the photocopy is a size other than standard sheet sizes or has unique cut marks, this is an indication that the photocopy may have been made on a machine with a roll-fed paper supply. Obviously, a photocopy from a sheet-fed photocopy machine may exhibit these same characteristics if it has been cut down from its original size. Because of this, paper supply should be used cautiously as a class characteristic.

MARKS

Since we are attempting to identify a machine manufacturer, the marks are not the unique trash marks by which an identification is made, but instead they are belt, roller and picker bar marks that are placed on the photocopy during its transit through the mechanical

portion of the machine. Examples of these types of marks are shown in Figures 2 and 3. Figure 2 is a Savin 770 machine. Savin liquid toner machines have a vertical line of any length running down the reverse side. This mark is typical of only Savin liquid machines. Figure 3 is a Canon NP-80. Canon liquid toner machines have a horizontal line of any length running across the bottom of the reverse side. This mark is typical of only Canon liquid toner machines. Both of these marks are caused by mechanics internal to the machine and are unique to these manufacturers.

FUSION METHOD

The fusion method is the most important class characteristic. It is also the most difficult to determine and extreme discretion should be used in its classification. This category, in conjunction with the other characteristics, will limit the possible manufacturers and models to a workable number. Care must be exercised when classifying the samples for the known standard file and the questioned document. The differences between the following fusion methods are subtle. Through experimentation, the optimal magnification was determined to be 100x. Greater magnification centers on too small an area and does not allow the viewer to clearly see the edges, paper fibers and marks left by the various rollers or belts on the toner. A lower magnification level centering on a larger area is suitable for determining the type of toner (dry or liquid) but not the particular method of fusion for that toner. The most important consideration for this characteristic is caution. The more known samples viewed, the greater the document examiner's expertise will become. Don't assume that the document was produced on one photocopy machine. The letterhead or body of text may have been prepared on more than one machine.

The following is a description of these fusion methods.

Radiant Heat

Radiant heat is intense heat applied to the toner during the fusing process. The dry toner appears like heated tar and has a glossy, bubbly appearance. Liquid toner is also classified in this category because heat is involved in the fixing process. The determination of the correct type of toner will eliminate any erroneous results. Liquid toner will have a flat appearance and the paper fibers will appear to be dyed. Examples of radiant heat machines are Xerox 1075 and IBM Copier II machines.

Heat and Pressure

Heat and pressure are exactly what their names convey. The dry toner is melted and then flattened by pressure. The pressure is in the form of a belt or roller (where the tension on the hard roller is slight). Laser

printers have been added to this category because they exhibit similar characteristics. Examples of this process are Eastman Kodak 100, 150 and Océ 1725.

Cold Pressure

Cold pressure is a unique fusion process and is found on both coated and plain-paper machines. The toner is dry and has not been melted by heat. The pressure is a roller, and under magnification the toner appears as though it could be scraped off the paper with a scalpel. The identifying factor is the absence of heat. A few examples of cold pressure machines are 3M 839, A.B. Dick 695 and Canon 120.

Hot Soft Roller

The hot soft roller fusion method is a combination of heat and a soft roller. The soft roller gives the dry toner a textured appearance, similar to the first application of paint on a wall. This category is not large, but care must be exhibited during classification so that the presence of a hard roller is not overlooked. Examples of this fusion method are Xerox 8200 and Gestetner 2002R.

Hot Hard Roller

This fusion process melts the dry toner and the hard roller presses the toner into the paper so that the paper fibers are evident. Examples of this method are A.B. Dick 7100, IBM 10, IBM Copier III and Royal 115.

Blotter

The blotter fusion method applies to liquid toner machines.

Air Dry

The air dry fusion method applies to liquid toner machines.

Hard Soft Roller

The fusion method classified as hard soft roller has been combined with the soft hard roller method. This reclassification resulted from the difficulty in determining which roller was positioned on the bottom during the fusing process. The toner is fused on the copy paper as it passes between these rollers prior to exit from the photocopy machine. If the hard roller is on the top, there will be tracks apparent on the surface of the toner. The paper fibers will also be evident. If the soft roller is on the top, the toner will have a textured appearance. The edge of the toner also acts as an aid in determining the order of the rollers. The toner will be slightly flattened if the soft roller is on the bottom. On the other hand, if the hard roller is on the bottom, the pressure will flatten the toner into the paper fibers. The specks of toner near the edge and on the surface of

the document will also contribute to the evaluation. The entire document should be examined because the identifying characteristics are not always apparent in every portion of the document. This, and the fact that more than one machine may have been used to prepare the document, emphasizes the importance of viewing the entire document. Examples of this fusion method are the Canon NP-250, Minolta EP-350Z, Mita DC-213RE and Panasonic FP-1520.

COLOR

The tenth class characteristic is the ability of the photocopy machine to produce color. Until a few years ago, this was not considered a significant category. The development of the color development cartridge by Canon and the advent of the personal photocopy machines have made this a significant category.

There are two types of color photocopy machines, the full-color and single-color machines. The full-color machines are the Xerox 6500, Canon Color T, Canon NP Color and 3M 137. Ricoh, Royal, Sharp and Toshiba have developed prototype full-color photocopy machines. The single-color copy machines have individual color cartridges. The paste-up originals and copy must be inserted for each desired color on a single sheet. Under 100x magnification, samples from the large single-color photocopy machines exhibit a small presence of the previous color used. The small personal machines tend to leave a heavier residue of the previous color. These small photocopy machines do not have a cleaning brush or blade to wipe off the excess toner. Examples of a few single-color machines are Canon PCs, Canon NP-250, Canon NP-270, Gestetner 2112RE, Mita DC-142RE, Sharp Z-60, Sharp SF-8200, Xerox 1035, Savin 7010, Toshiba BD-4121 and 3M 537. The Toshiba BD-4121 and 3M 537 are both manufactured by Toshiba. They are the only single-color dry toner machines that house two colors simultaneously. Savin has developed a prototype single-color liquid toner photocopy machine. This machine uses their Landa Process Technology. The four colors, red, blue, green and black, are housed in the machine simultaneously. These five prototype color photocopy machines, the full-color Ricoh, Royal, Sharp and Toshiba and the single-color Savin machine, are planned for delivery during 1986.

An integral part of the Office Copy Standards File is the collection of known standards. These standards include information on foreign as well as domestic photocopy machines. Because most office copy machines are not manufactured in the United States, foreign models refer to those machines not marketed in the United States. These known samples provide the source for the database, which spans the period of 1950 through 1985. The database currently contains information on approximately 1,500 models. Where samples are available, microscopic slides have been prepared for comparison with questioned documents. In addition

to the samples, literature is maintained on the manufacturers and individual models. The Office Copy Standards File is updated by attendance at trade shows and subscriptions to Datapro, Dataquest, Buyers Laboratories, Inc., Info-Market and Office Equipment and Products (OEP).

A Similar Models File is also maintained. This is a cross reference of similar photocopy machines. Approximately 500 known models are sold under numerous names manufactured by a few companies. The data stored are manufacturer's name, model and similar machines. The identification of photocopy machines is becoming as difficult as typewriter identification. Unlike typewriter manufacturers, the photocopy manufacturers are not copying each other's machines. The large manufacturers are selling them to smaller companies to distribute under their own label. Therefore, one photocopy model may have several clones.

CONCLUSIONS

In summation, the computerization of the physical characteristics of office copy machines drastically reduces the possible manufacturers of the questioned document. There are few cases where the specific model or a manufacturer can be determined and the determining factor in these instances is usually the unique marks produced by a specific machine or manufacturer.

The paper type, toner and fusion method are the most valuable class characteristics for limiting the possible manufacturers. The fusion method is the most difficult of these physical characteristics to classify. Date of introduction, manufacturer and model are three other categories that have not been mentioned as a searching tool. Each of these groups may be searched separately. The date of introduction is the most significant of these three categories since it can be used to assist in dating a document.

REFERENCES

- Falls, R. (1983).* Copier supplies must match the machine for optimal use, *The Office*.
Unley, S. M. (ed.) (1985). Datapro Reports on Copiers and Duplicators.

SUGGESTED READINGS

- Kelly, J. H. (1983).* Classification and identification of modern office copiers, Forensic Sci. Foundation Inc., Colorado Springs, Colorado.
Lile, J. E. and Blair, A. R. (1976). Classification and identification of photocopies: a progress report. *J. Forensic Sci.* 21:923-931.

IDENTIFICATION OF MECHANICAL PRINTING PROCESS CHARACTERISTICS

Robert G. Hacker

Rochester Institute of Technology
Rochester, New York

The printing process may be classified into two main categories, direct contact and nonimpact, based on how the image is transferred to the substrate—the material that is the image carrier.

In this paper we will deal with the traditional or direct impact methods of printing. These methods are called letterpress, offset lithography, gravure and screen-process printing. Also included will be a brief description of steel-die engraving and thermography.

LETTERPRESS PRINTING

Historically, letterpress printing, in some form, was the dominant process from the time multiple copy printing began until the 1960s. Its fundamental characteristics are a raised surface covered with ink placed

in contact under pressure with a suitable image carrier so as to transfer the ink to the substrate.

Figure 1 is a schematic representation of a simple letterpress operation. Figure 1(a) shows the letterpress plate with a raised surface covered with a film of ink. The raised surface may be composed of type characters, halftone illustrations or a combination of both (Bluden 1968).

Figure 1(b) shows the substrate—in this case paper—with the impression made after the plate has been squeezed into the surface. Not only has part of the ink film been transferred, but an actual impression of the image has also been crushed into the paper fibers.

Referring again to Figure 1, we can see that the process of pressing the ink into the paper creates some squashing or squeeze-out of ink around the edge of the image.

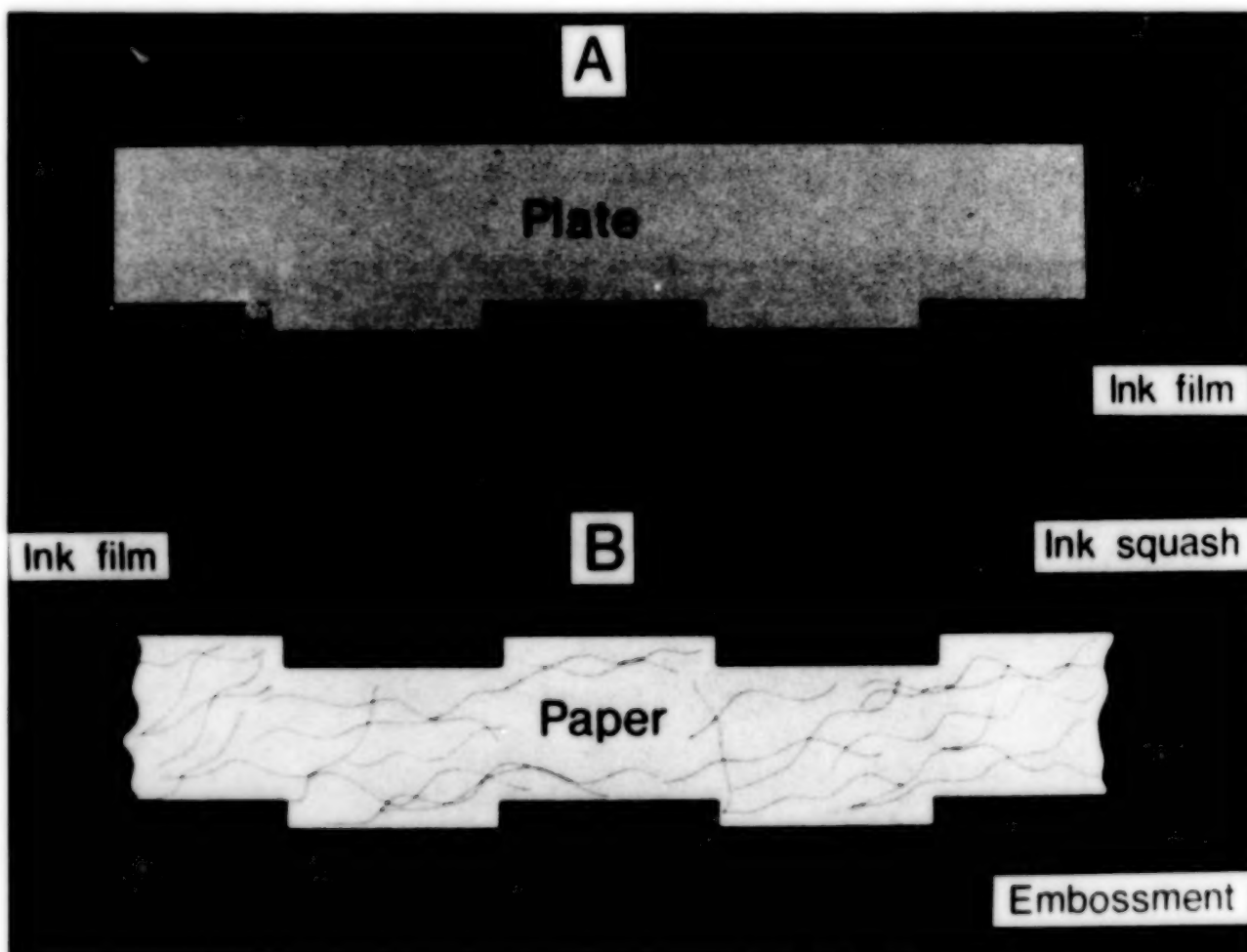


Figure 1. Schematic of letterpress printing.

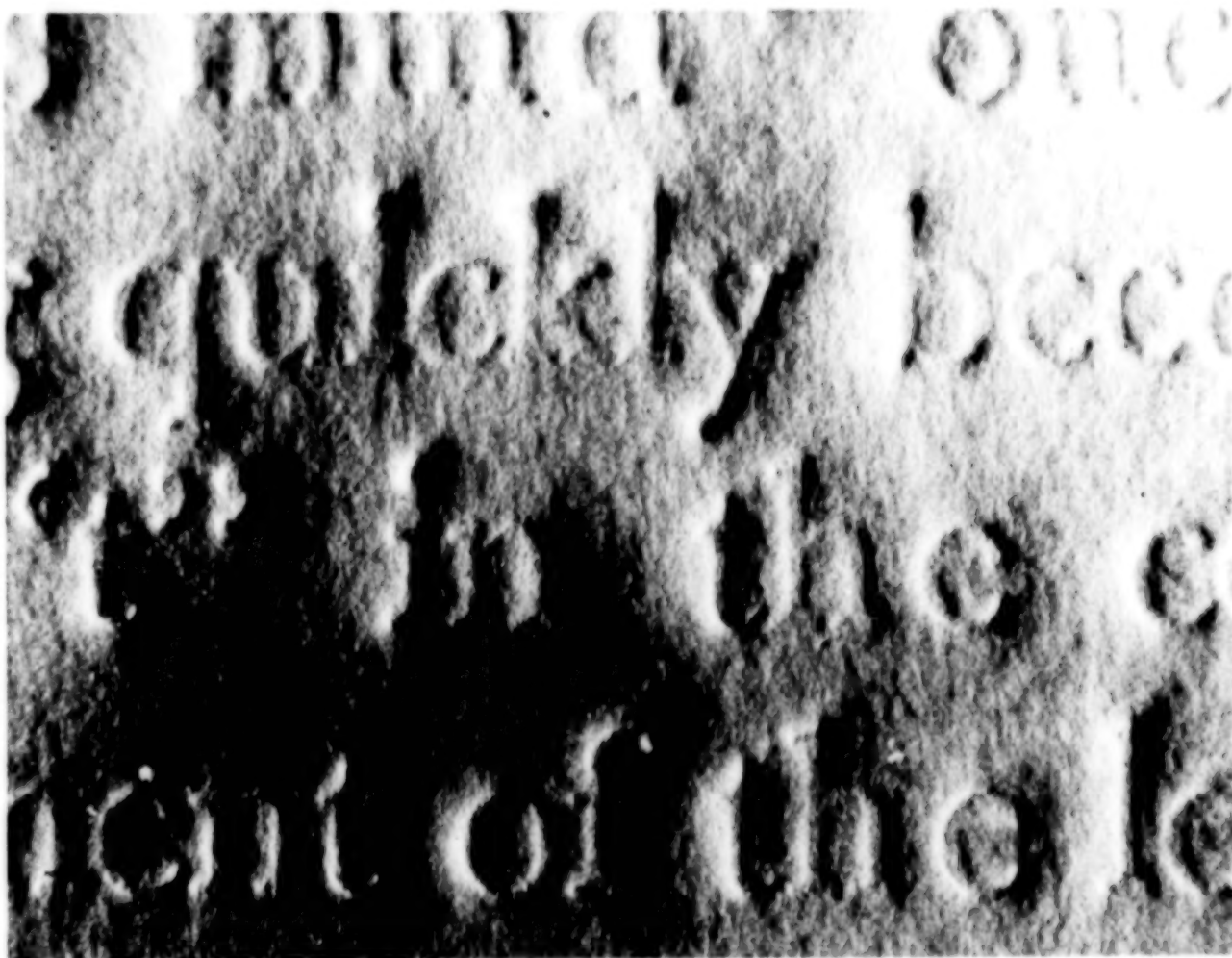


Figure 2. Letterpress embossing showing on the reverse side of the paper under oblique illumination.

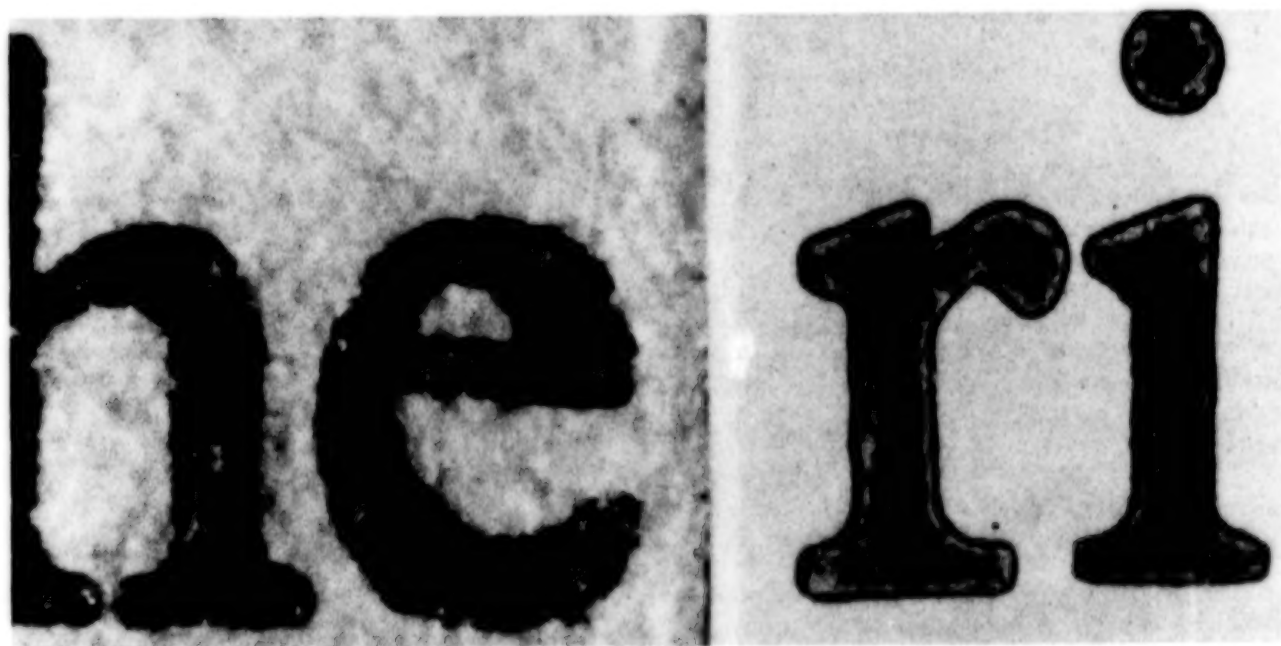


Figure 3. Letterpress image on smooth and rough paper surface.

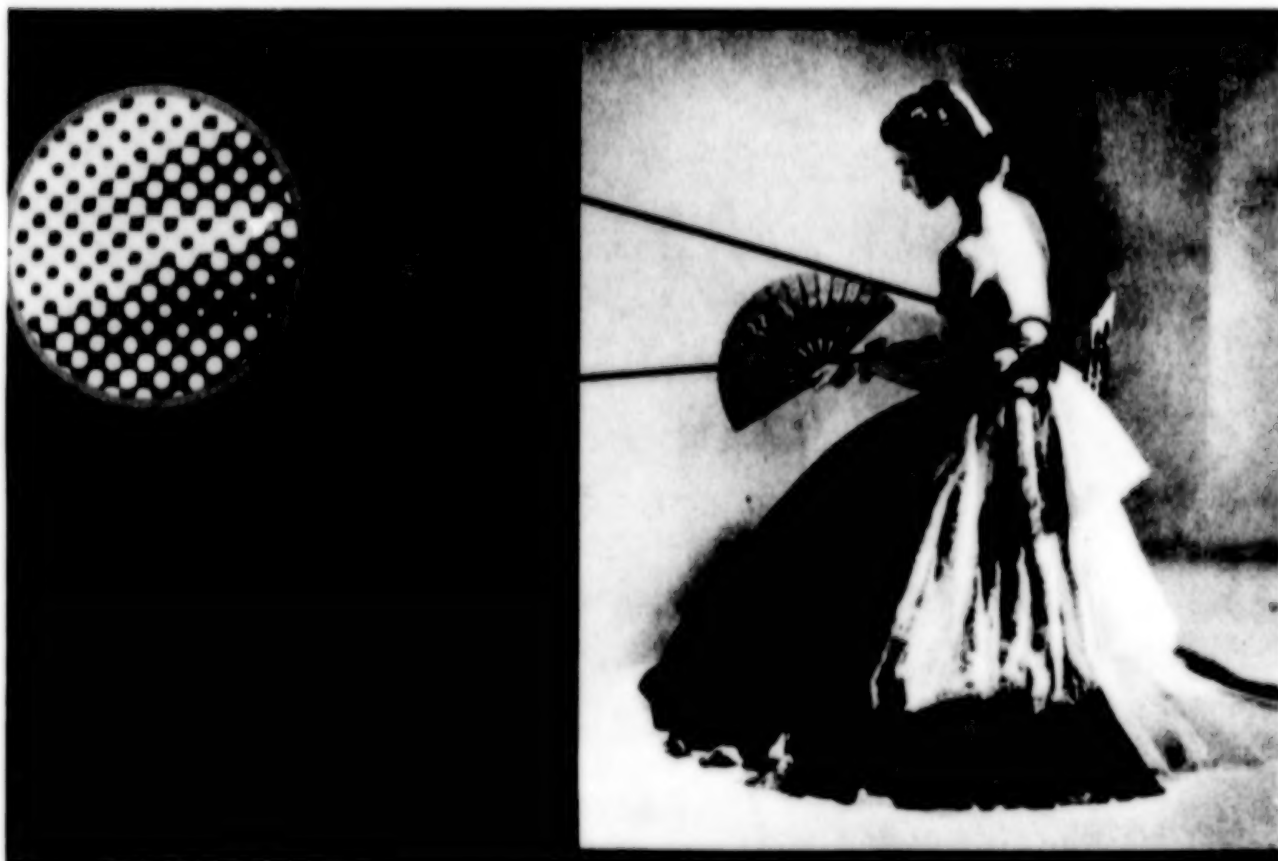


Figure 4. Magnification of halftone dots.

A word of caution needs to be injected at this point. The plate materials used for letterpress printing, with a few exceptions, have undergone significant change in the past several years. In the past, the plate components were hard materials, beginning with wood and converting to metal with the advent of moveable type around 1450. Currently, the great majority of plate materials used for letterpress printing are photopolymers, which are somewhat less hard (Hoffman 1985). Although embossing and a raised image on the reverse side are present, they may not be as evident. If the document is on harder, smoother paper, like that used in magazine printing, it may be harder to detect. In addition, soft, compressible paper like newsprint may not show such clear markings on the reverse if used with photopolymer plates.

The embossing effect shows on the reverse side, as can be seen from Figure 1, and is readily detectable under oblique light conditions. This phenomena is clearly illustrated in Figure 2, which shows the back of a sheet of paper that has been printed by the letterpress method (Bluden 1968).

Figure 3 shows an actual letterpress image on two different kinds of paper stock (Bluden 1968). The paper stock on the left is typical of softer papers like newsprint. The image still shows squeeze-out around the edge but not with such distinction. The center areas of the characters are definitely lighter in hue caused

by the thinner ink film thickness. Edges are still defined, however, by the pushed up film of ink squeezed to the side by the impression pressure.

The paper stock on the right is a typical example of a smoother, hard-surfaced paper stock. The center of the image appears lighter with a definite halo around the circumference of the image. This might be the effect one would observe on a paper like that used in typical glossy magazines.

Images in printing, as mentioned earlier, are composed of both text and illustrations. Text and some illustrations are called linework. That is, they are composed of solid images of varying thicknesses. Typical examples of line images are the satirical cartoons found on the editorial pages of many newspapers.

Most pictures found in printed material, however, are composed of numerous tiny dots of varying sizes that, when viewed at normal reading distance, blend together to become a continuous image (Okuyama 1984-85). These types of illustrations are called halftones and may be in one color or in several colors depending on the desired effect. Such an illustration is shown in Figure 4 (Bluden 1968).

The size of the individual dots varies from very small to where they begin to overlap so that only a small part of the surface is free of ink. In this way, the tonal range from light to dark is represented, with the eye blending them together to form a continuous pattern of tonal

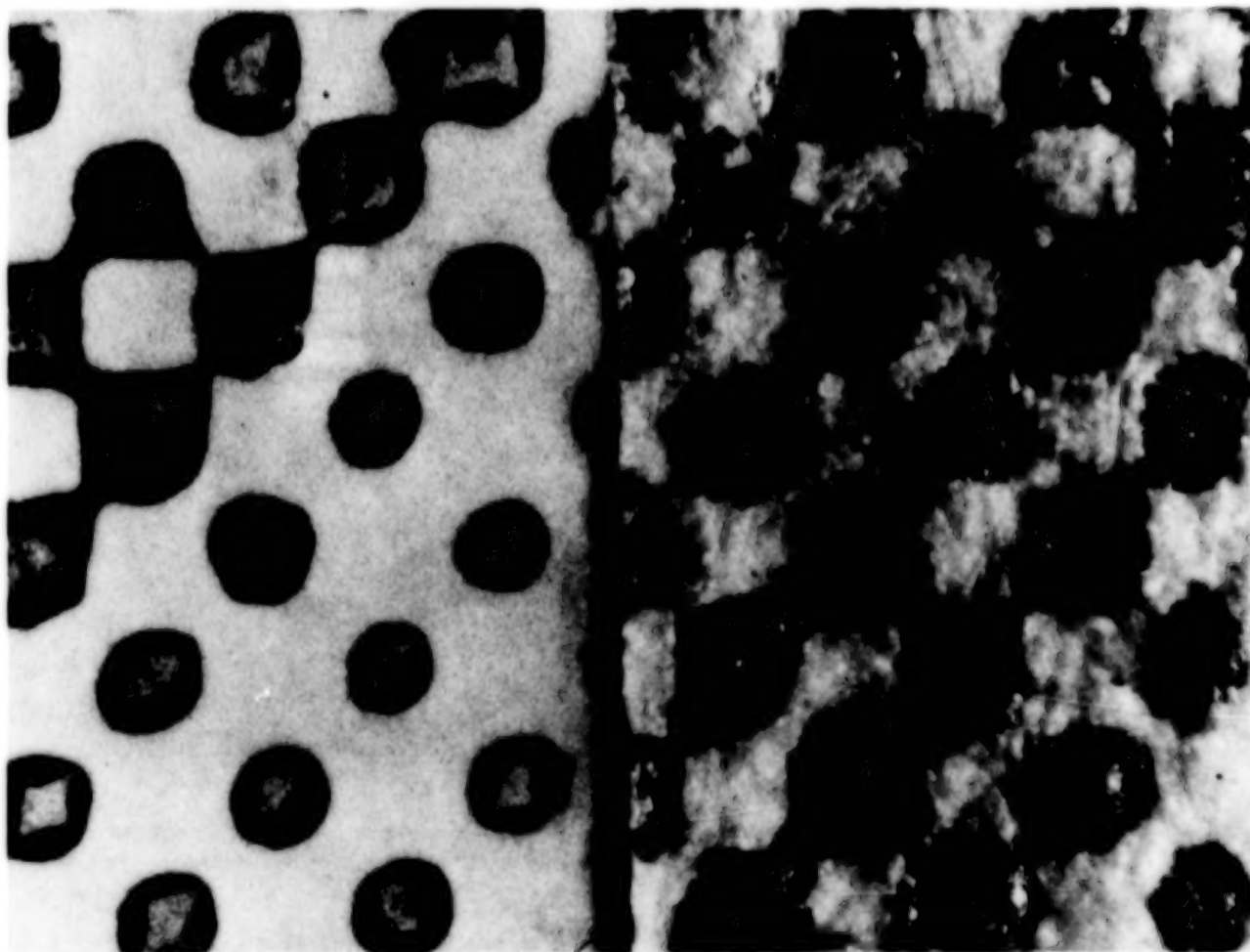


Figure 5. Letterpress dots on two different paper surfaces.

renderings. This technique of converting continuous tone photographs to a method for successful printing is common to all of the contact printing processes. The micro-image of the individual dot, however, is unique to the particular process.

Figure 5 illustrates typical letterpress halftone dots on two types of paper (Bluden 1968). On the left is a soft paper like newsprint and on the right, a smooth, hard paper used in publication printing.

As with the line image on newsprint, squeeze-out of ink, while still apparent, is not as distinct as with the better grade of paper stock. In both cases, however, the distinct halo effect can be observed where the center of the dot is lighter than the outer edges. Figure 6 shows a letterpress dot on soft paper under high magnification (Bluden 1968). There is enough ink flow to fill in the uneven surface of the paper at the edge, while just back from that the valleys in the paper still show white.

Flexography

A major segment of the letterpress market is served by a process called flexography. A number of years ago it was called aniline printing for the character of the

dyes used as colorants in the ink. In the past, various grades and compositions of rubber were used as plate materials. Today, most plates are made from photopolymer materials (Bolza-Schunemann 1985).

These new materials give sharper definition to the printed images and permit finer screen rulings in the halftones, contributing to overall image quality.

Figure 7 shows a typical flexographic press installation (Bluden 1968). In this system, a roller turns in a bath of highly fluid ink, which is then transferred to a knurled roller called the anilox roll or transfer roll. This roller acts as a metering device in delivering the proper amount of ink to the plate surface.

Some flexographic systems currently used in newspapers have a flexible doctor blade riding the surface of the anilox roll to skim off excess ink, thus providing a more uniform inking of the plate (Bolza-Schunemann 1985).

The plate cylinder contains the photopolymer or rubber plate, which has the proper relief between the printing surface and the bottom of the plate. Ink is then transferred from the surface of the plate to the substrate. In the flexographic printing system, the substrate may be paper, polyethylene, other plastic-like substances or even various kinds of foils.



Figure 6. Letterpress halftone dot under high magnification.

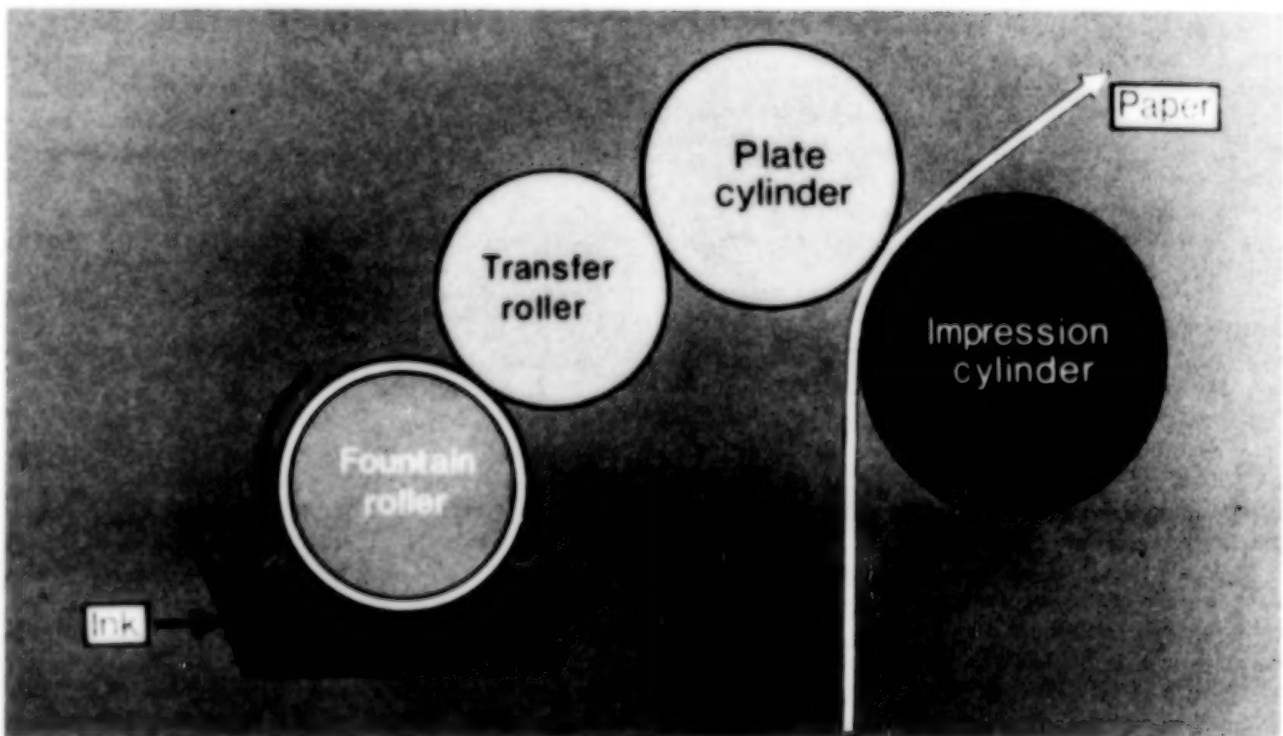


Figure 7. Schematic illustration of a flexographic press.

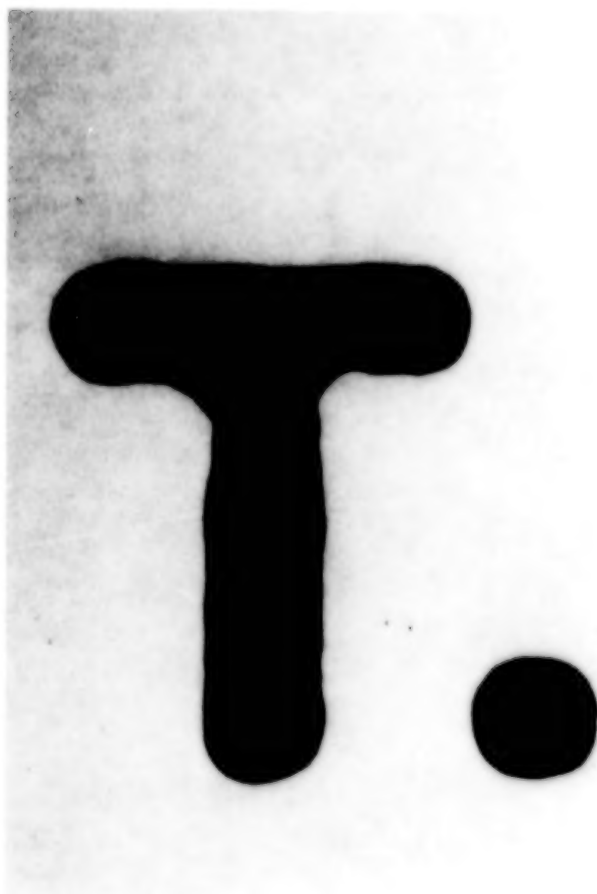


Figure 8a. Flexographic image on polyethylene.

The impression cylinder provides a backup for the plate cylinder. The distance between the plate and the impression cylinder is adjusted to compensate for the variation in substrate thickness and the amount of squeeze or impression desired. The amount of impression is one of the critical variables in determining the quality of the image produced in the printing process. This is true regardless of which process is being evaluated.

Traditionally, flexography has been a major process for printing all kinds of packaging materials. Its ability to print on thin materials without puncturing the surface or to print without any ink transfer or pickup in nonimage areas are its strong points.

In identifying the image, there is still squeeze-out of ink toward the edge of the image, which is more apparent on polyethylene than on paper. Figure 8 illustrates this point (Bluden 1968).

Figure 8a is a flexo image on polyethylene. While the plate material is somewhat softer, the relatively hard, smooth surface of the polyethylene causes the ink to push to the edges.

Figure 8b is on paper. The combination of a flexible plate and the softer, more compressible surface of the paper give a more uniform coverage while still showing the telltale dark halo around the edge.

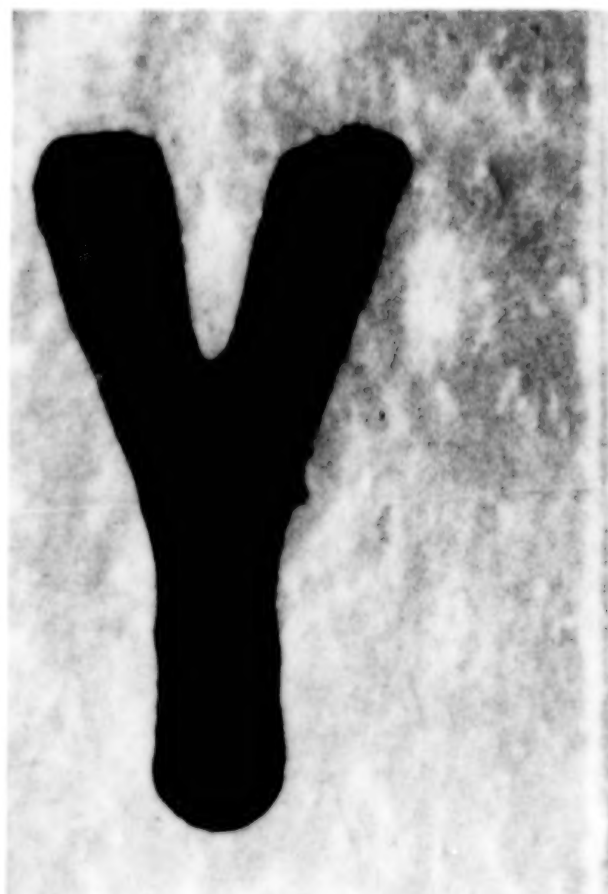


Figure 8b. Flexographic image on paper.

OFFSET LITHOGRAPHY

Offset lithography is the dominant process used today in the printing industry. It began with the creation of an image with a grease crayon on a piece of limestone. When wetted and then inked, the ink adhered to the greasy image and not to the stone area. Paper could then be applied to pick up the ink on the greasy part of the stone.

This process still exists in essence, but the mechanics are vastly different. Early examples of this so-called stone lithography are some of the famous posters of Toulouse-Lautrec.

In modern offset printing, metal plates have been substituted for the stone, with ink dispensing roller systems, dampener rollers to wet the plate and a paper handling system for either sheet or roll stock. Such a system is shown in Figure 9 (Bluden 1968).

At the top of the figure is an ink fountain that feeds down through the multiple rollers to spread the ink evenly and to control the amount delivered to the plate. The illustration shows a press system that rotates counterclockwise. This is necessary for the dampener rollers to moisten the nonink-receptive areas of the plate so that as they pass under the inking rollers only the image area, which is chemically ink-receptive, will

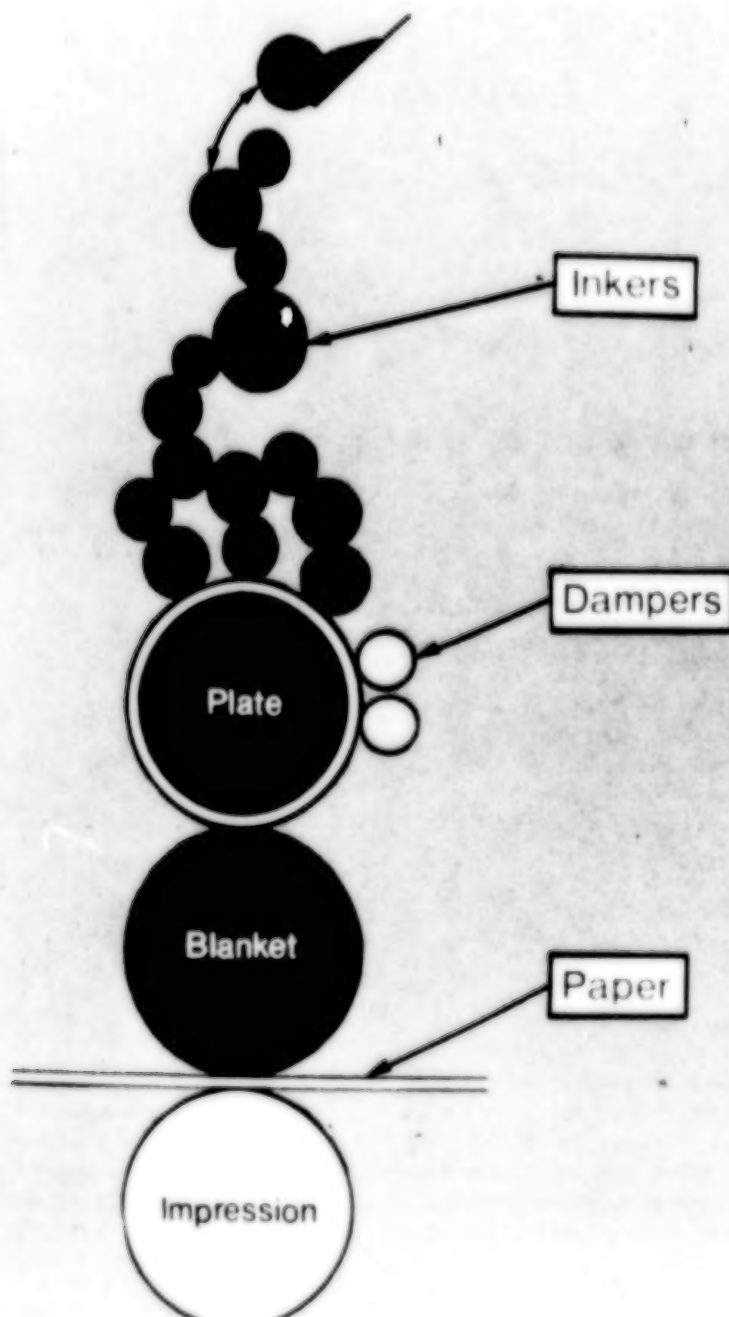


Figure 9. Schematic illustration of an offset press.

receive a coating of ink. What results is a plate that is selectively inked only in the image area.

Continuing in its counterclockwise revolution, the plate bearing ink in the image area comes in contact with a rubber blanket, which accepts the ink transfer to its surface. The blanket then revolves further, coming into contact with the paper and transferring the ink onto its surface. As with the letterpress process, an impression roller is needed to provide the squeeze necessary for image transfer.

In some press installations, a second printing system is the mirror image of the one in Figure 9 (Bluden

1968). That is, instead of an impression cylinder as shown, another blanket cylinder is present with all of the related plate, ink and dampening mechanisms. The two blanket cylinders provide the squeeze necessary for ink transfer. At the same time they allow the paper to be printed on both sides with one pass through the press unit. Such an installation is called a perfecting press.

Several units placed in line permit printing of multiple colors with accurate registration on one pass through a press (Parnau 1985). The offset process also allows a rather even lay-down of ink because a plane



Figure 10. Halftone and line image produced by offset.

surface is pressed against another plane surface. There is no traditional halo effect on halftone dots, solids tend to be more even and the squeeze-out of ink on type and other line work is not evident (Richardson 1984). Figure 10 shows a typical halftone and type image printed by the offset lithographic process (Bluden 1968).

It can be seen from this image that there is some fuzziness around the edges as compared to the sharp outline of the letterpress impression. Halftone dots are also less defined with more tendency for ragged outlines.

Figure 11 shows a comparison of multicolor printing by both the letterpress and offset processes (Bluden 1968). The image on the left is obviously the letterpress halftone with its sharply defined dots and readily apparent halo effect. The image on the right has been produced by the offset printing process and shows dots with a characteristically less sharp outline. Keep in mind that these images have been magnified considerably and those dots might be only .010 inch in diameter on the original printed sheet.

As was mentioned earlier, offset lithography is the dominant process in today's printing industry. It is used

on a great variety of substrates producing materials from packaging through publications of all types, including newspapers (Holland 1984). Presses for this process range from small machines found in many office duplicating installations to mammoth press lines printing major newspapers such as *The Washington Post*.

GRAVURE

Gravure or intaglio, as the process is sometimes called, involves creating a recessed image in a suitable plate material, filling that recess with ink so that none remains on the raised surface, then putting a substrate in contact to transfer the ink from the recess to the substrate.

The process began with flat plates, then evolved into cylinders for image carriers. With the advent of cylinders and related press design changes the process began to be called rotogravure. The word has been simplified in terms of trade usage to gravure, which is the common description used today.

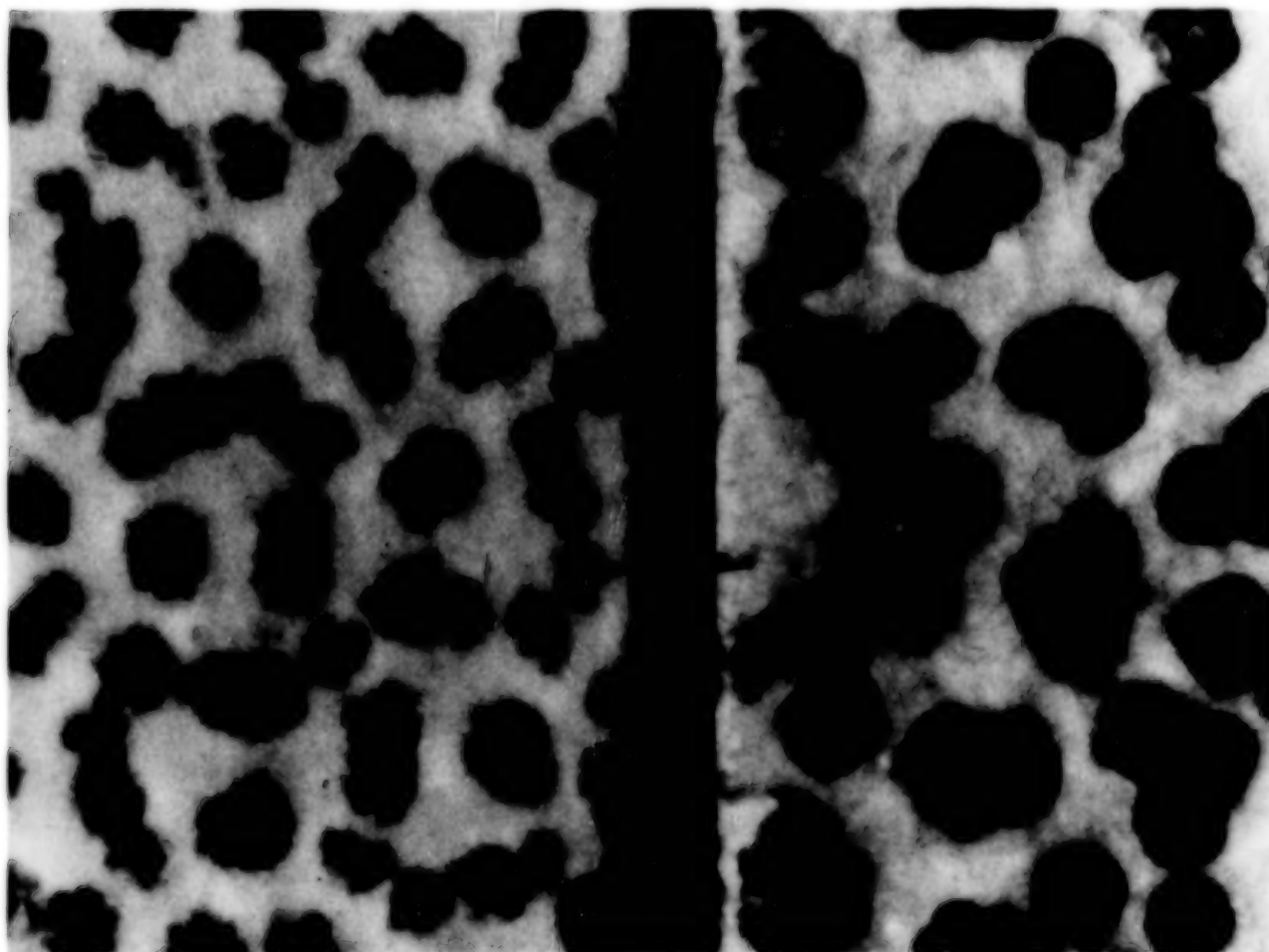


Figure 11. Comparison of multicolor images produced by letterpress and offset.

Figure 12 shows a typical gravure press design (Bluden 1968). In this process, the cylinder has the image recessed into it in the form of cells. These cells can all be of the same size with varying depths to change the ink density or can be of varying sizes but have the same depth. The metal between the cells acts as a support and defines the size of each cell. This metal is called a land (Garneau 1984).

As Figure 12 illustrates, the lands support the doctor blade, which provides a wiping action on the surface of the gravure cylinder as it revolves. Excess ink is thus doctored off, leaving only the portion in the cells that will form the printed image.

As the cylinder continues to revolve, it comes into contact with the substrate, which is backed up by an impression cylinder. This cylinder helps in the ink transfer. On many modern presses an electrostatic assist is used so that the paper or other substrate is charged with one polarity and the cylinder with another. Thus, the attraction between the opposite charges helps to secure a more uniform emptying of the cells onto the material being printed.

The cylinder continues around, picking up its next supply of ink from the fountain, having the excess doctored, imaging the substrate and the cycle continues.

One of the major defining characteristics of gravure printing is the cell pattern. In order for an image to be formed, everything printed by gravure is composed of minute cells. This is true if a photograph is being reproduced or whether line work such as type is being printed.

This cell pattern may vary from 120 to 300 lines per inch, depending on the substrate and the quality desired. Figure 13 clearly illustrates the cell pattern in type as shown on the right portion of the image. The left half of the illustration shows the typical uneven nature of a solid that results from trying to cover a large area completely with cells separated by lands.

Gravure, as stated earlier, has a characteristic pattern of cells in the final printed image. It was also stated that cells can vary either in depth or size depending on the way the image was created. This pattern can clearly be seen in Figure 14 (Bluden 1968). The portion of the figure to the right shows the process with same size cells. Both images are examples of two colors being printed one over the other. The portion of the figure on the left shows the process where cells vary in size but are consistent in depth. It is important to remember that regardless of the process, all images produced by the gravure process have a cell pattern.

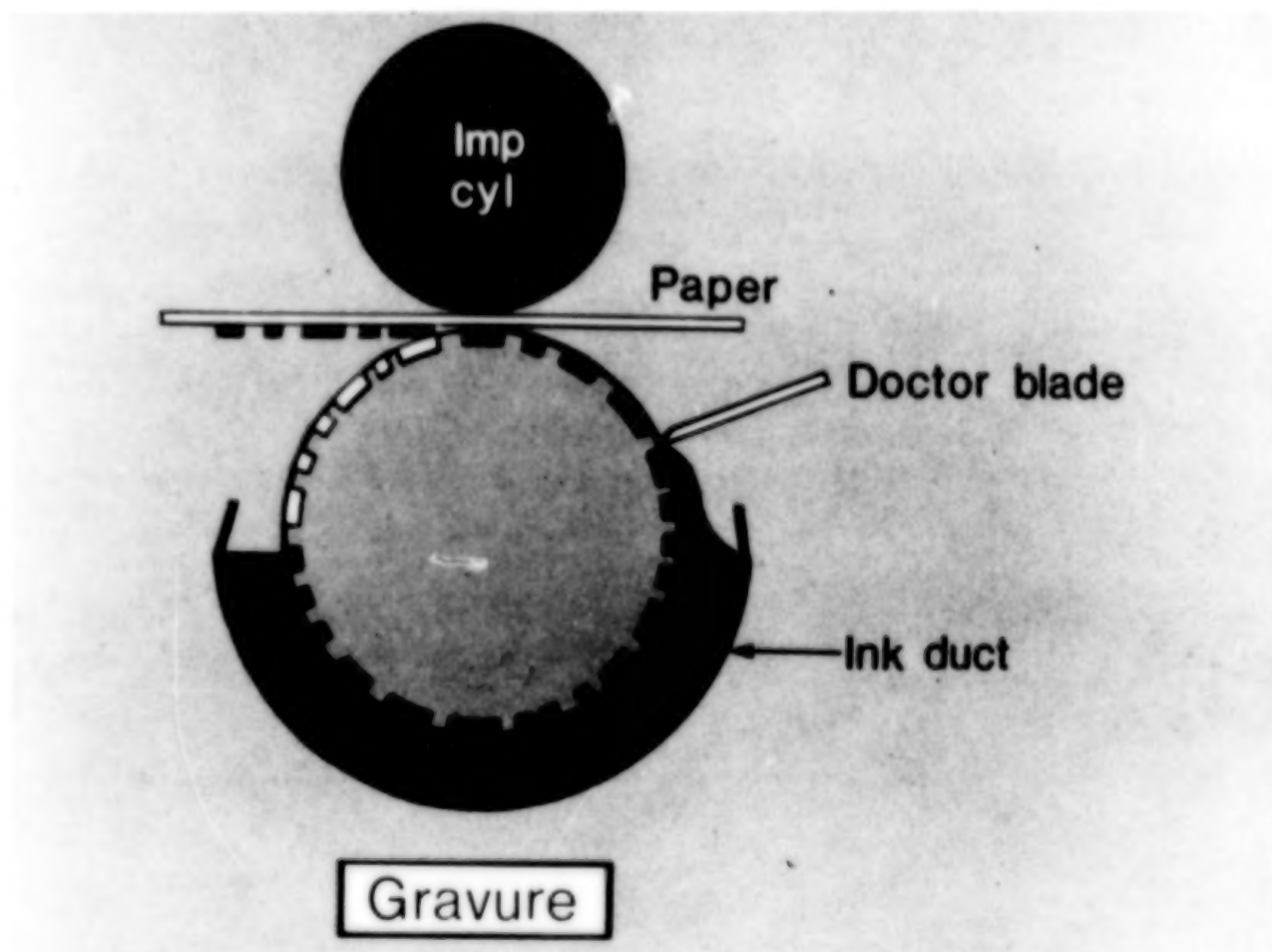


Figure 12. Schematic illustration of a gravure press.



Figure 13. Gravure cell pattern in type and the surface of a solid printed by gravure.



Figure 14. Illustration of gravure with same-size and varying size cells.

A large market for gravure exists in the Sunday supplement business for newspapers. An example of this is *The New York Times* Sunday magazine. Some long running publications such as *TV Guide* are printed by gravure. Packaging of all kinds is produced by this process as is the small trademark image on M & M candies.

SCREEN-PROCESS PRINTING

Screen-process printing is sometimes erroneously called silk-screen printing. This stems from the fact that originally the woven fabric that supported the image-forming material was silk. Currently, the support screen is made of various types of synthetic woven materials and some metal screens include stainless steel (Kyle 1984).

The screen is stretched tightly on a metal or wooden frame that not only holds the mesh firmly but also provides a dike in which the ink can be applied and forced through the mesh onto the material being printed.

Areas of the screen are blocked out selectively with a masking material that can be applied by hand or

through the use of photosensitive resists. In the latter case the mesh is coated with a photosensitive emulsion, then exposed through a suitable negative to ultraviolet light, thus hardening the exposed areas. Next, the unexposed areas are washed out, leaving a stencil master that allows the passage of the ink.

The ink is placed in the box form and the form placed in proximity to the material to be printed on. A squeegee traverses the box form, slightly distending the screen to bring it in contact with the substrate, and the ink is squeezed through the open part of the stencil creating the image. Figure 15 is a schematic of a typical screen process system (Bluden 1968).

In this figure, the screen is shown stretched on the frame with the image area open acting as a stencil for the ink, which is pressed through onto the substrate. Some screen printing is done by moving the squeegee by hand. In production situations, however, the process is completely mechanical with screen and squeegee movements and ink supply completely automated.

One of the strong points of screen-process printing is the heavy ink film that can be laid down. It is possible to transfer much more ink than by any other process. This is also a drawback in that much care must

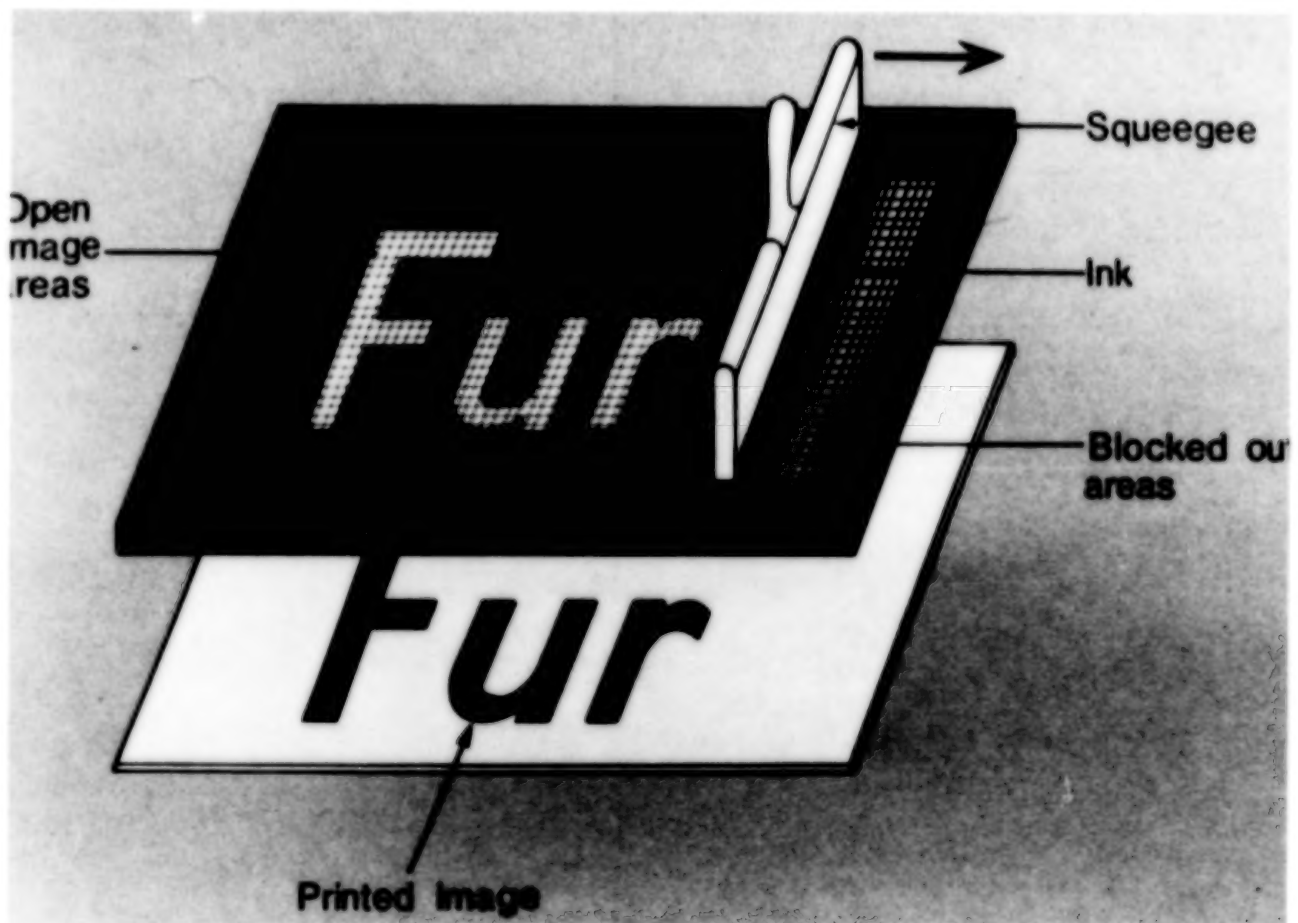


Figure 15. Schematic of a screen-process printing system.

be taken to ensure that images are dry before coming in contact with other materials. Consequently, screen-process presses have extensive drying racks on the delivery end of the press to assist in keeping each sheet separate from others so that no set-off of the ink will occur.

One large use for this process is for posters in black and white and also in process color. Art prints of various kinds as well as textiles are also produced by this process (Frecska 1984). There are applications in label printing, printing on bottles and odd shapes such as plastic illuminated signs.

RAISED IMAGE PROCESSES

Steel-Die Engraving

Steel-die engraving is used to raise the image applied to the sheet. In this process two dies, one female and the other male, are used. The image is produced by having the paper squeezed between the dies under great pressure to form a relief (Anthony 1984). Oblique illumination will show the impression of the male die on the back of the paper and the surface will have the

image raised. Figure 16 shows both sides of a steel-die embossed image (Bluden 1968).

Steel-die engraving prints relatively small sheets of paper or lightweight paperboard. Its products are mainly items of engraved stationery such as letterheads, envelopes, calling or visiting cards and social announcements. Other uses of steel-die engraving are for greeting cards and school certificates (Strauss 1968).

Thermography

Thermography is a relatively inexpensive method for achieving about the same effect as with steel-die engraving. In this process, the image is printed on the substrate using mostly letterpress methods (Crist 1984). Then the sheet is passed through a machine that cascades a thermosetting resin material on it. The resin adheres to the ink film and the remainder is shaken off. The sheet is then passed through a suitable heat source where the resin is fused onto the sheet, causing a raised surface. Figure 17 illustrates this process (Bluden 1968).

Under high magnification the raised image can clearly be seen. If this piece of printing were examined from the back, there would be no embossed image into the



Figure 16. Steel-die engraved image showing embossing on the back.



Figure 17. Raised image produced by thermography.

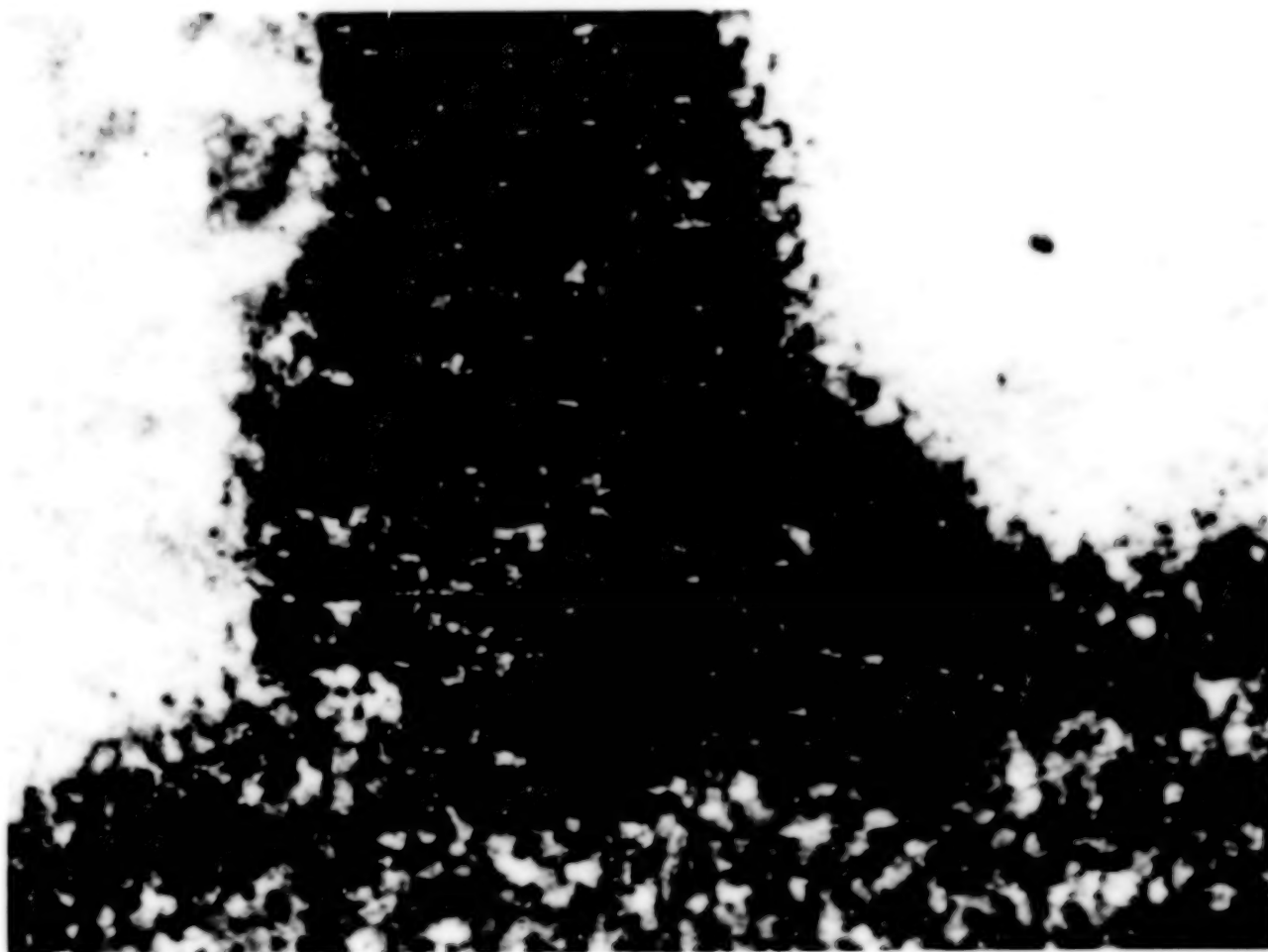


Figure 18. Magnification of thermographic image showing fused resin particles.

paper as with steel-die engraving. However, if the piece has been produced by letterpress there might be reverse embossing indicating pressure from the image side.

Figure 18 clearly shows the resin particles fused together to form the raised image produced by thermography (Bluden 1968). One of the characteristics of this process is the stray particles that often adhere to the sheet in nonimage areas. Such a particle is clearly seen in the upper right quadrant of the figure.

The major uses for thermography fall in the same categories as for steel-die engraving. Business cards and letterheads are a major portion of this work.

CONCLUSIONS

Figure 19 illustrates the major points to keep in mind when identifying an impact printing process. Edges of type should be examined to see if there is a distinct halo effect, if the edges are somewhat fuzzy but coverage is relatively uniform, if there is a distinct cell pattern or if there is a defined fuzziness indicating a screen mesh pattern.

Halftone dots should be examined to see if there is a halo pattern, if the dots are relatively uniform with somewhat fuzzy edges due to the paper fibers, if the dots have a distinct cell pattern or if there is a slight mesh fuzziness around the periphery of the dot and screen interference in the overall pattern (Feldman, personal communication).

Solids should be examined for evenness of coverage. Letterpress solids might show a halo effect around the edges as opposed to a relatively even coverage to the edge with offset. Gravure will show some unevenness due to the cells and a faint pattern might be observable. Screen process solids might show a discernible mesh pattern particularly at the edges of the solid.

Embossing is a characteristic to look for and is associated with letterpress and steel-die engraving processes.

Ink film thickness will normally be heaviest with screen-process printed materials and thinner on the other processes. Keep in mind that with multicolor printing, several ink films may be overprinted, giving the impression of a single heavy ink layer.

The kind of substrate should also be taken into consideration. Newsprint and similar uncoated papers can be printed on by any process. Finer grades of paper

POINTS TO STUDY

EDGES OF TYPE

HALF - TONE DOTS

SOLIDS

EMBOSSING

INK FILM THICKNESS

KIND OF STOCK

NATURE OF JOB

DEFECTS

Figure 19. Points of comparison in image analysis for printing process identification.

Table 1. COMPARISON OF PRINTING PROCESS CHARACTERISTICS

	LETTERPRESS	OFFSET LITH	GRAVURE	FLEXO	SCREEN PROC
Embossing	X				
Ink Squash	X			X	
Even Inking		X			
Zig-zag Edge			X		X
Cell Pattern			X		
Fine Screen/ Rough Stock		X	X		

such as coated and filled publication stocks can be printed on by any process. However, when it comes to thin grades of polyethylenes, foils and similar light papers, flexography probably would be used.

In this context, the screen ruling for printed work is often related to the surface smoothness of the stock. In general, the smoother the paper stock the finer the screen ruling of the halftones. There are exceptions to this pattern, however. Gravure is one example of this where a 300-line cell pattern might be used on several different kinds of stock.

The nature of the work affects the selection of the process. Flexography and gravure are used widely in packaging. Offset is used across the board for most commercial printing as well as in the production of the majority of newspapers. Screen process is used heavily in posters, signs and in some textile printing. High-quality color images would very likely be printed by offset, or for long run work of more than 100,000 impressions, gravure might be a reasonable choice.

Certain defects might also provide clues to the process in question. For example, dropped-out highlight dots that show a marked change in tonal gradation by their absence might indicate a letterpress halftone. Such dots, if missing in offset, are not so apparent to the eye in terms of sharp tonal changes. The ragged cell patterns of gravure type are another instant giveaway.

Smoothness of ink coverage in large solids can also be another indicator of the particular process.

Table 1 is a general comparison chart of fundamental process characteristics discussed in this paper. It must be remembered that sometimes a single clue is enough to identify a particular process and at other

times several indicators in concert will be needed to clearly determine the process involved.

REFERENCES

- Anthony, G. H. (1984). Minor printing processes, Paper, Film and Foil Converter, 58:86.
- Bluden, B. W. (1968). Printing Process Identification, Letterhead, Surrey, U.K.: PIRA.
- Bolza-Schunemann, H. B. (1985). The future of letterpress presses, Newspaper Techniques, July/August, p. 4.
- Crist, N. (1984). Raising the question of thermography, In-Plant Printer, 24:26.
- Frecska, T. (1984). Troubleshooting edge faults, Screen Printing, 74:97.
- Garneau, G. (1984). Lasers and gravure printing, Editor & Publisher, 117:28.
- Hoffman, W. (1985). Development and testing of photopolymer printing plates, Newspaper Techniques, July/August, p. 12.
- Holland, C. (1984). New ways with plates and films, British Printer, 97:13.
- Kyle, J. (1984). New commercial horizons for screen printing, British Printer, 97:21.
- Okuyama, S. (1984-85). Printing technology and the halftone dot, Graphic Arts in Japan, 24:22.
- Parnau, J. R. (1985). How to choose the right press, Folio, 14:121.
- Richardson, P. (1984). Matching new paper and inks, Printing World, 212:36.
- Strauss, V. (1968). The Printing Industry. Printing Industries of America, Washington, D.C., p. 290.

ANALYSIS OF DUPLICATOR (PHOTOCOPY) TONERS

R. N. Totty, G. S. Kemp, B. German, G. S. Metcalfe and E. Hubbleday

Home Office Forensic Science Laboratory
Chepstow, Gwent, England

The examination of photocopy documents to determine their source has by now become a routine task undertaken by many document examination laboratories.

There are several possible approaches to this problem, one of which is to compare defect marks on the photocopy introduced during the copy process from marks on the copier drum, glass platen or lid. Another approach is to examine the distortion produced by the optical system on the copier. A third approach is to examine the chemical composition and physical properties of the paper and toner used.

The value of each approach depends on the circumstances of each individual inquiry. In some instances examination of defects alone will provide a clear result; in others comparison of chemical and physical properties will do likewise. The choice of techniques used is at the discretion of the examiner, depending on what it is desired to achieve, what instrumentation, if any, is available and what type of control samples can be acquired.

In this paper, some aspects of the third approach, the use of chemical and physical techniques to examine and compare paper and toner, are considered, but it must be understood that other solutions may well be available to solve the problems described.

Any examination of photocopies is made difficult by the substantial range of machines now available. The rapid advances in technology make many machines obsolete within only 1 or 2 years of introduction. The retail market is highly competitive, which leads manufacturers to change machine design and capability frequently. Simply collecting and collating information on new, or apparently new, photocopiers is now a time-consuming task.

While most manufacturers are willing to cooperate with official inquiries into criminal activities, a few are not and some distributors of machines made in the Far East are apparently unable to provide detailed information at all. At times some manufacturers have supplied information that has subsequently been shown to be incorrect.

Our approach is, therefore, empirical in that we have sought to develop methods to differentiate toners and papers that rely but little on information supplied by other sources. However, in certain individual inquiries discussions with scientists employed by photocopier manufacturers, technical representatives and service engineers have been particularly profitable and have led directly to the acquisition of valuable evidence. We would stress that each case be considered on its merits and action taken accordingly.

At an early stage in our study we noted that photocopy toners could be differentiated by infrared spectroscopy (Kemp and Totty 1983), and it was subsequently shown that a detailed analysis of the toner spectrum provided much information on the chemical composition of the toners (Williams 1983). Most toners are now applied as dry powders and consist of carbon black mixed in varying proportions with organic resins, which are the medium for attaching pigment to paper (with, in a few toners, added inorganic materials). It is these resins that contribute to the infrared spectra of the toners (Figure 1).

Spectra from photocopy documents prepared on approximately 150 different models of photocopiers from more than 30 manufacturers have now been examined and have been classified into 10 groups on the basis of general absorption characteristics. With care, further discrimination may be achieved within each group and the use of improved techniques for recording spectra, for example, Fourier transform infrared spectroscopy (FTIR) can further improve levels of discrimination. Infrared spectroscopy is not particularly sensitive to the presence of minor components in mixtures and certain manufacturers supply different toners for specific uses that cannot be distinguished; other manufacturers have changed toner composition with no noticeable effect on spectra.

Chemical analysis of toner is not entirely reliable as a means of identifying make and model of machine. In examining toner from known sources it has almost invariably been found that the toner present corresponds with toner samples provided by the manufacturer or agent. However, in a few instances foreign toner of a type not supplied or recommended by the manufacturer has been detected. The identification of make or model of photocopier from a chemical analysis of the toner must always be seen in this light.

Chemical analysis of toner is particularly useful in the negative sense—a difference between the toner on a questioned document and the toner used in a photocopier thought to have been used indicates clearly that the photocopier was **not** used, and such elimination of potential sources has obvious value.

In the positive aspect, chemical analysis of the toner can never be conclusive in itself and must be seen as part of the process of identification. The most that can be said in the absence of any other evidence in the form of defect marks, etc., is that a particular photocopy machine **could** have been used to produce the questioned document.

Many photocopy documents examined at this laboratory are second or third generation copies, having

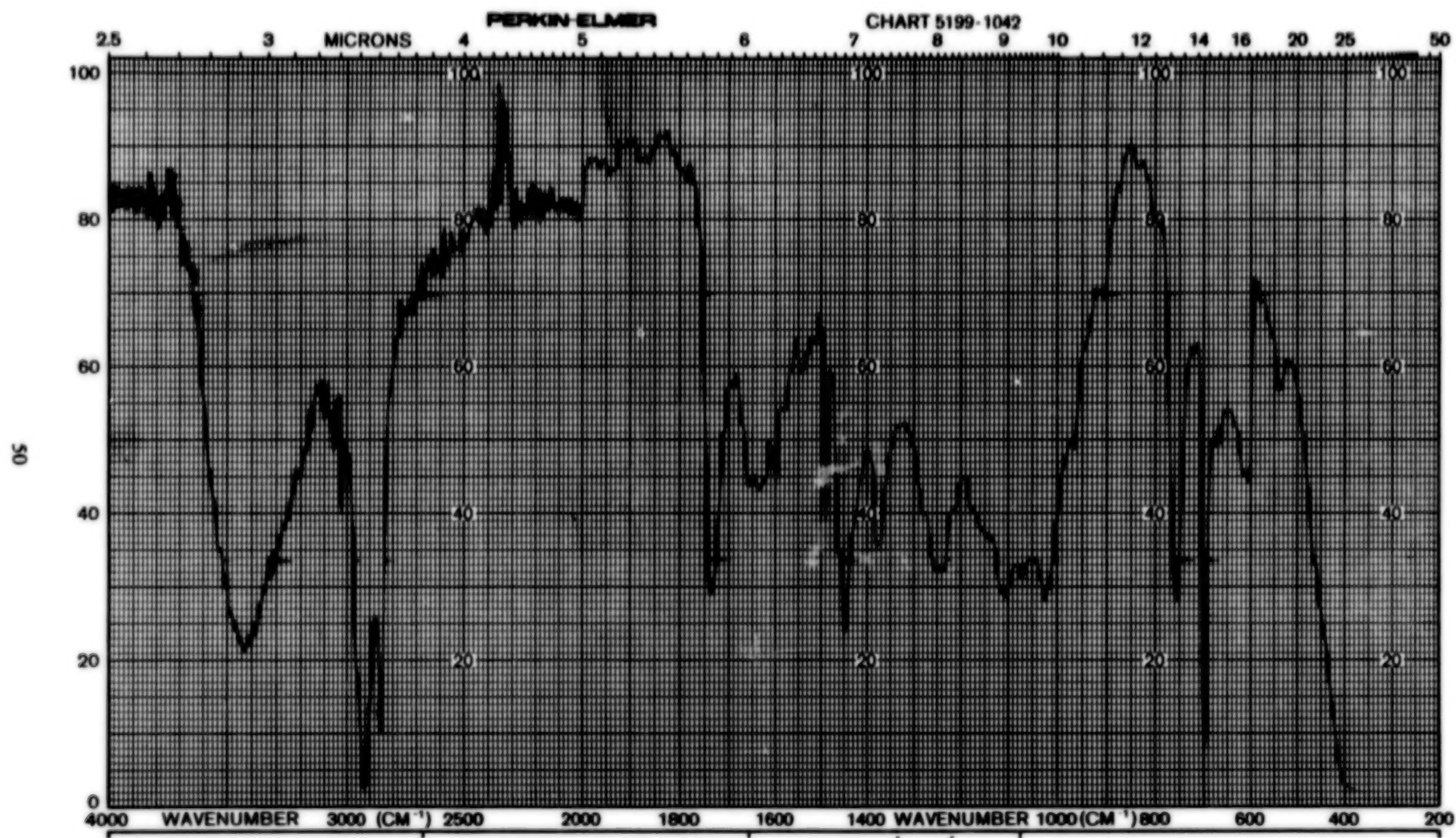


Figure 1. Typical infrared spectrum obtained from toner sample on paper from Canon NP70 photocopier.

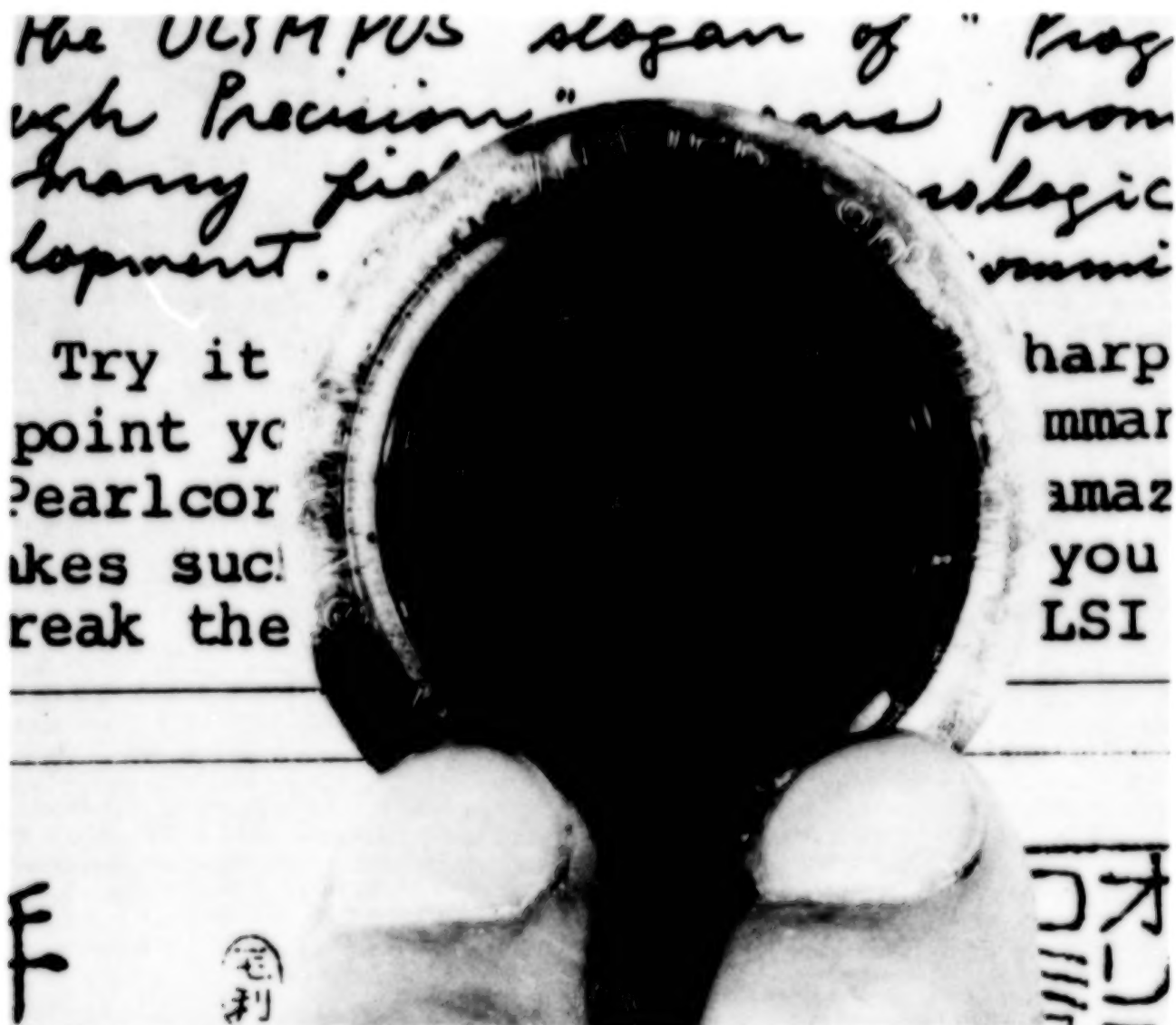


Figure 2. The use of the 3M magnetic viewer to detect magnetic material in photocopy toner.

been copied successively on different machines. If a questioned document can be linked to two or more photocopiers by means of defects, chemical analysis of the toner can often indicate which of the photocopiers was the last in the series.

Occasionally it is necessary to show that a document was, or was not, produced at a particular time. In one such case, a photocopy of a will dated January 1974 was submitted for examination. The copy was first produced by the beneficiary of the will in 1979 who stated he had received it within a few days of the signing of the will; the original has never been seen by any other person and the testator died in 1975. The laboratory was asked if the will was genuine and examination showed that the toner on the photocopy corresponded with Xerox toner type H and toners used in only three other machines: Gevafax X12, A.B. Dick 980 and Lumoprint LX5. Xerox toner type H was introduced into the United Kingdom in 1974, but the first impor-

tation by Xerox was in July. Other Xerox toners in use in early 1974 differed significantly from the toner on the photocopy will and the other photocopiers using similar toners were not introduced into the United Kingdom until 1979 or later. These facts do not support the beneficiary's story.

Some photocopiers have a magnetic delivery system for the toner powder. One type of delivery system uses a magnetic carrier to transfer toner, but a second type uses toner powder that has magnetic material incorporated in it. The toner powders containing magnetic material, when fixed onto the paper as part of the photocopy image, exhibit magnetic properties and can be magnetized by gentle stroking with a permanent magnet (Welch 1985). The magnetism can be detected using systems designed for viewing the signal on magnetic recording tapes. The 3M magnetic viewer (Figure 2) is particularly easy to use although liquid systems such as Magnasee or Edvue fluids are perhaps

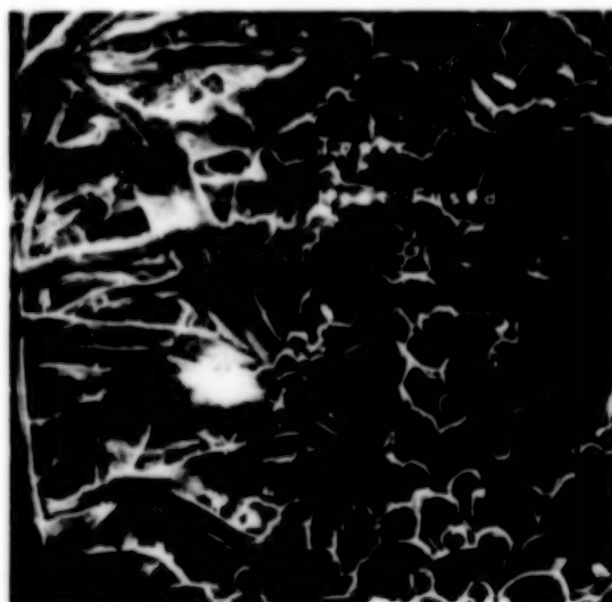
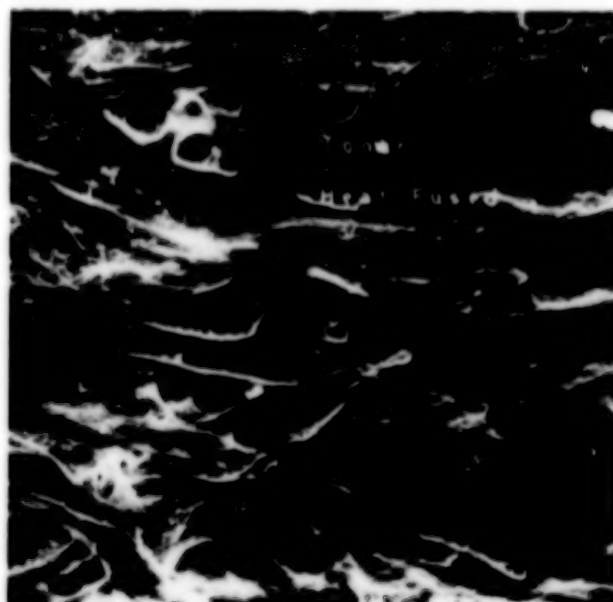


Figure 3. Surface morphology of wet and dry toner deposits on paper when examined at magnification of 200x using the scanning electron microscope, as exemplified by samples from Canon NP80 and OCE 1900 photocopiers.

more sensitive. By this procedure magnetic toners can be distinguished quite readily from nonmagnetic toners.

The scanning electron microscope (SEM) can be used as an analytical device to record X-ray spectra of the toners, which, when provision is made for possible contributions from the paper, can give qualitative elemental data from elements of atomic number greater than 10 (Heuser 1984; Warman *et al.* 1984).

Information can also be gained by examination of the surface morphology of toner areas on photocopies, either by high-power optical microscopy or scanning electron microscopy (Warman *et al.* 1984).

Toners used in plain paper photocopiers are of two types—wet, which suspends pigment particles in a volatile hydrocarbon solvent, and dry. The wet type is now used in very few models but can be distinguished quite readily from dry toner because the toner covering is thin and the liquid flow across paper fibers leaves clear outlines of the fibers (Figure 3). Dry toners, applied as a powder, cover the paper surface more thoroughly.

The appearance of toner surface on photocopies prepared using dry toner depends very much on the method of fixing used. Some photocopiers use heat alone, others cold pressure and some use combinations of heat and pressure. It has been shown that toners can be discriminated readily by examination at 200x using scanning electron microscopy, although the range of features observed did not fit into well defined categories (Warman *et al.* 1984).

We have recently commenced an investigation of the relationship between surface morphology and the infrared spectrum of the toner.

The purpose of this paper is to describe the properties of these two toners and their relationship to each

other, with particular reference to toners in machines using different mechanisms for fusing the toner to the paper surface—heat fusing with little or no pressure and cold pressure alone. X-ray spectra have also been obtained from these toners, giving the inorganic content. No attempt has been made to make a comprehensive survey of all makes and models available; the rapid changes in photocopier design make any such survey obsolete before it is completed. The information given should be seen as an example of what can be achieved from this approach to photocopier examination.

TONERS USING COLD-PRESSURE FUSING

Samples from 12 copiers known to employ cold pressure alone as the fusing method have been examined. These are listed in Table 1.

Photographs of samples of toner taken from photocopies produced on each of the machines listed in Table 1 are shown in Figure 4; these photographs were taken on an SEM at 200x. The toner particles are evenly sized and remain discrete, although there is clear evidence

Table 1. PHOTOCOPIERS USING COLD PRESSURE ALONE

Olympus Panoly E102	Olympia Omega 001
Agfa-Gevaert X1	Olivetti Copia 1000
Roneo-Alcatel 208	Gestetner 2020
CPF Satellite	Esselte Dymo Develop 20
Roneo-Alcatel 1005	Canon NP126
Pitney-Bowes 5200	Olympia 303

of particle compression. There is no suggestion of using or melting of the toner resin. All the samples have similar surface morphology and cannot be distinguished on this basis.

Infrared spectra of toners from these machines are all weak and obtained only with some difficulty, indicating that the organic content is low (Figure 5). Reproducibility is poor and while all spectra fall into the same general category, corresponding to those of acrylic resins, no further discrimination is possible.

Most of the toners in these samples from cold-pressure-fused photocopiers can be magnetized, indicating that ferrous material is used as the toner carrier. Two machines, the CPF Satellite and the Pitney-Bowes 5200, use toner that could not be magnetized and hence has no ferrous content.

The X-ray spectra of the toners from the CPF Satellite and the Pitney-Bowes copiers confirmed the absence of iron in any quantity (Figure 6), the strong calcium peaks originating from the paper filler and not the toner.

The X-ray spectra of the toners from eight of the copiers—Olympia Omega 001, Gestetner 2020, Roneo-Alcatel 208, Olympus Panoly EI02, Olivetti Copia 1000, Olympia 303, Roneo-Alcatel 1005 and Esselte Dymo Develop 20—show significant amounts of iron, but little else that can differentiate toners from these machines (Figure 7). The toners from the Canon NP-126 and Agfa-Gevaert X1 copiers, as well as containing iron, also contain significant quantities of silicon (Figure 8), enabling these toners to be distinguished from the other magnetic toners.

To summarize, toners from the 12 copiers could *not* be distinguished by examination of surface morphology or by the infrared spectra; examination of magnetic properties and X-ray spectra showed that 2 of the 12 had low iron content and that 2 of the 10 toners containing iron also contained significant amounts of silicon.

TONERS USING HEAT FUSING WITHOUT PRESSURE

Samples from 10 photocopiers known to use heat fusing have been examined. Some are representative of large families of Xerox machines that use essentially identical mechanisms. These are listed in Table 2.

In photographs taken at 200x using an SEM (Figure 9), the individual toner particles are no longer visible and the toner is completely fused into a solid mass that sits on the surface of the paper. The toner surface is highly reflective and toners examined under low magnification have a glossy, dense black appearance. All samples taken from machines using heat fusing alone have similar surface morphology and cannot be distinguished on this basis. None of these toners contained any detectable ferrous material on the basis of magnetic tests. However, infrared spectra of these toners reveal significant differences in their chemical composition.

Table 2. PHOTOCOPIERS USING HEAT FUSING WITHOUT PRESSURE

Toshiba BD727	A.B. Dick 980
Agfa-Gevaert X10	Olivetti Copia 1400
Xerox 2600	Xerox 3450
3M VHS	Olympia 1000
Gestetner 2010	IBM Copier II

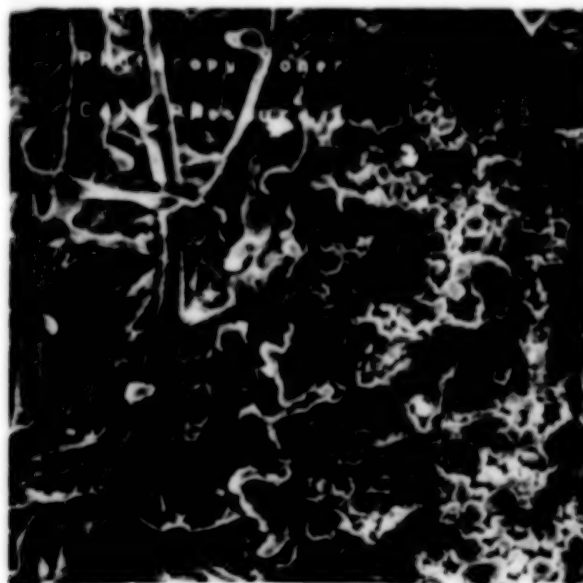
The toner from the Toshiba BD727 contains a moderately strong absorption band at 2090 cm^{-1} , which is clearly a stretching vibration of a multiple-bonded group (Figure 10). The only commonly available structure absorbing at 2090 cm^{-1} is the CN group in an organic cyanide. This component in the toner has been identified as Prussian blue, ferric ferrocyanide (Williams 1983) and distinguishes this toner from those used in the other photocopiers using heat fusing alone. The X-ray spectrum from the toner from the Toshiba BD727 can be distinguished from other spectra on the basis of the moderate iron and sulphur peaks—the iron originating from the Prussian blue detected by infrared spectroscopy (Figure 11).

The toner used in the Xerox 3450, Xerox 2600 and A.B. Dick 980 is a bisphenol fumarate ester. The infrared spectrum is characterized by the bands at 1600, 1570 and 830 cm^{-1} indicating a p-disubstituted benzene nucleus and the broad peak at 1250 cm^{-1} due to the vibration of the $(-\text{CH}_2-\text{O}-\text{aromatic})$ structure (Williams 1983) (Figure 12). The X-ray spectra of the toners from the three machines could not be distinguished further (Figure 13). These spectra indicate significant silicon content of the toner (the potassium originates from the paper).

The infrared spectrum of the toner used in the Olivetti 1400 machine is similar to that of the toner used in the Xerox 3450, Xerox 2600 and A.B. Dick 980 but differs in the relative intensities of the absorptions caused by the ester group and the aromatic nucleus (Figure 14). The infrared spectrum of the toners used in the 3M VHS and the Gestetner 2010 are similar. The X-ray spectrum of the toner from the Olivetti 1400 shows a high organic background and weak iron and copper peaks, which distinguish it from other X-ray spectra recorded (Figure 15).

The toner used in the Agfa-Gevaert X10 appears to be basically a methacrylate (absorption bands at 1730, 1170 and 1120 cm^{-1})/styrene (absorption bands at 700, 750, 1450 and 1500 cm^{-1}) copolymer (Figure 16). The infrared spectra of the toners used in the Olympia 1000 and the IBM Copier II are similar. The X-ray spectra of the toners from these machines are indistinguishable from those of the toners from the Xerox 3450, Xerox 2600 and A.B. Dick 980 machines.

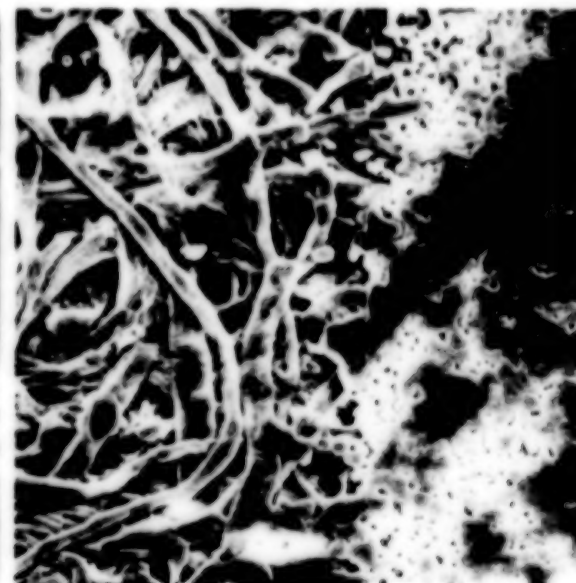
All the infrared spectra from the toners used in heat-fused systems were obtained without difficulty, are



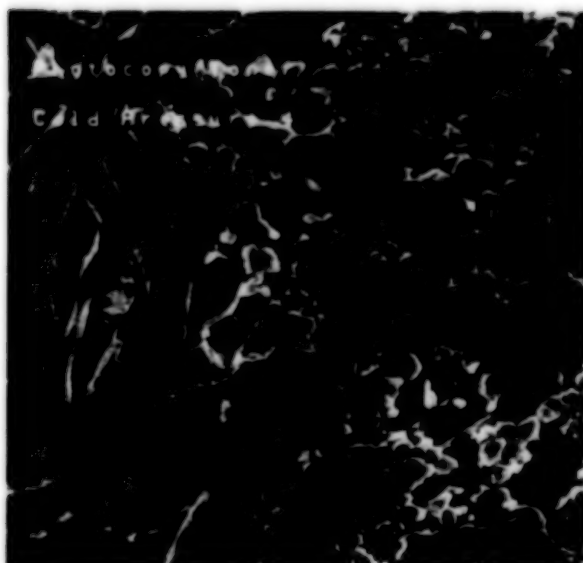
Olympus Panoly E102



CPF Satellite



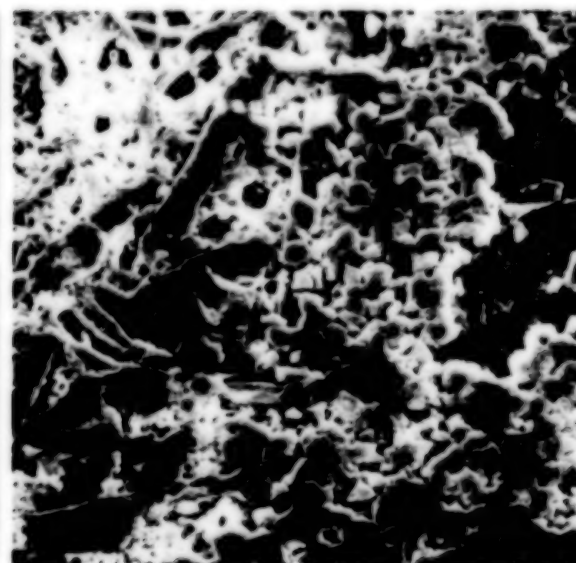
Agfa-Gevaert X-1



Roneo Alcatel 1005

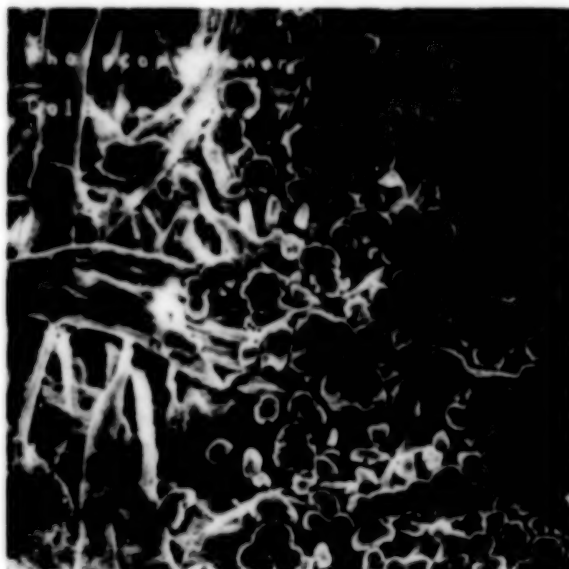


Roneo Alcatel 208

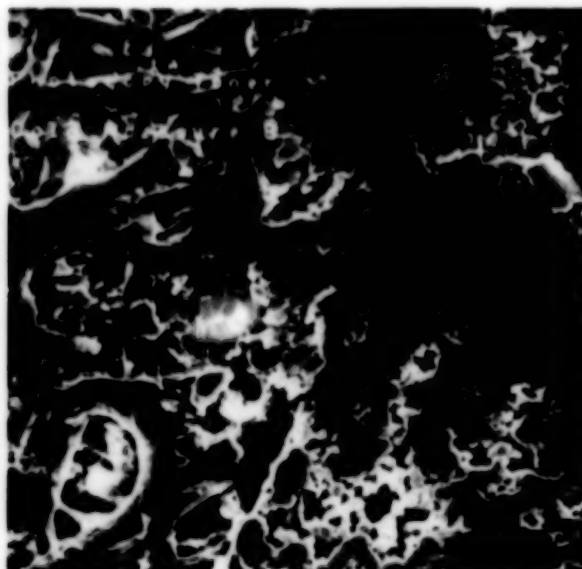


Pitney-Bowes 5200

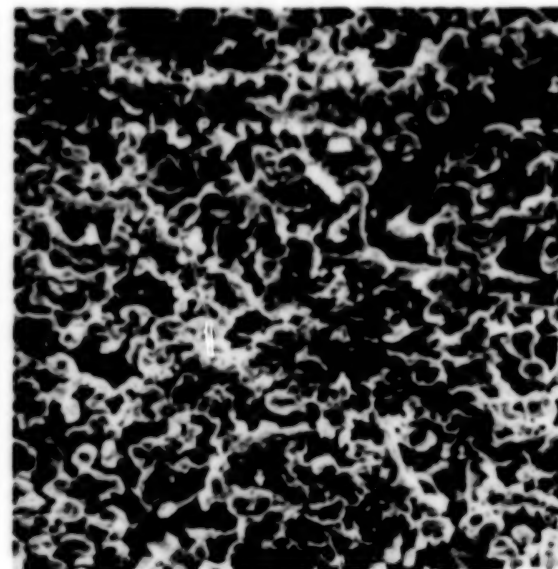
Figure 4a. Variations in surface morphology of some dry photocopy toner deposits fused by cold pressure as shown by scanning electron microscope photographs (magnified 200x).
Olympus Panoly E102, CPF Satellite, Agfa-Gevaert X-1, Roneo Alcatel 1005, Roneo Alcatel 208, Pitney-Bowes 5200



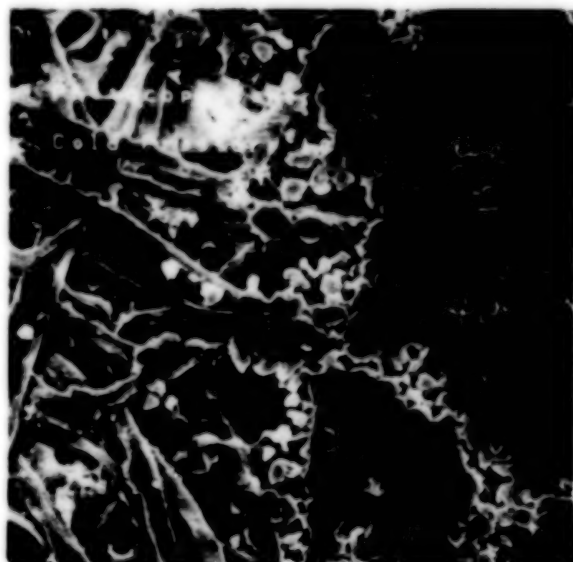
Olympia 303



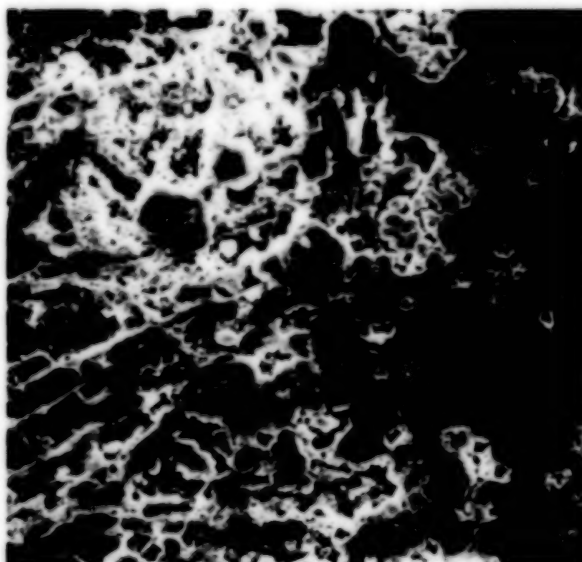
Olympia 001



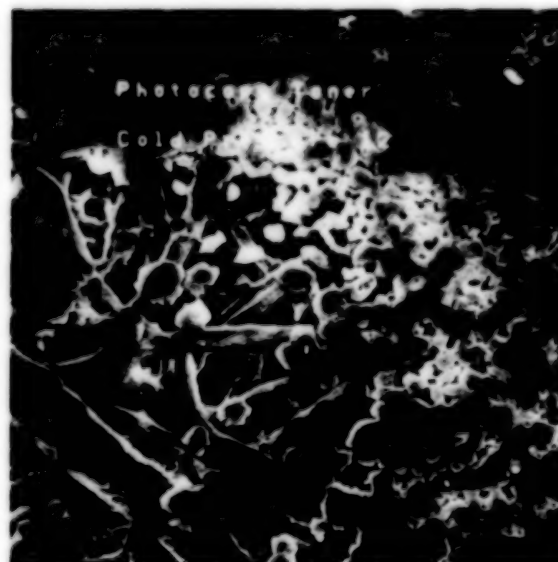
Olivetti Copia 1000



Gestetner 2020



Esselte Dymo Develop 20



Canon NP126

Figure 4b. Variations in surface morphology of some dry photocopy toner deposits fused by cold pressure as shown by scanning electron microscope photographs (magnified 200x). Olympia 303, Olympia 001, Olivetti Copia 1000, Gestetner 2020, Esselte Dymo Develop 20 and Canon NP126 photocopiers.

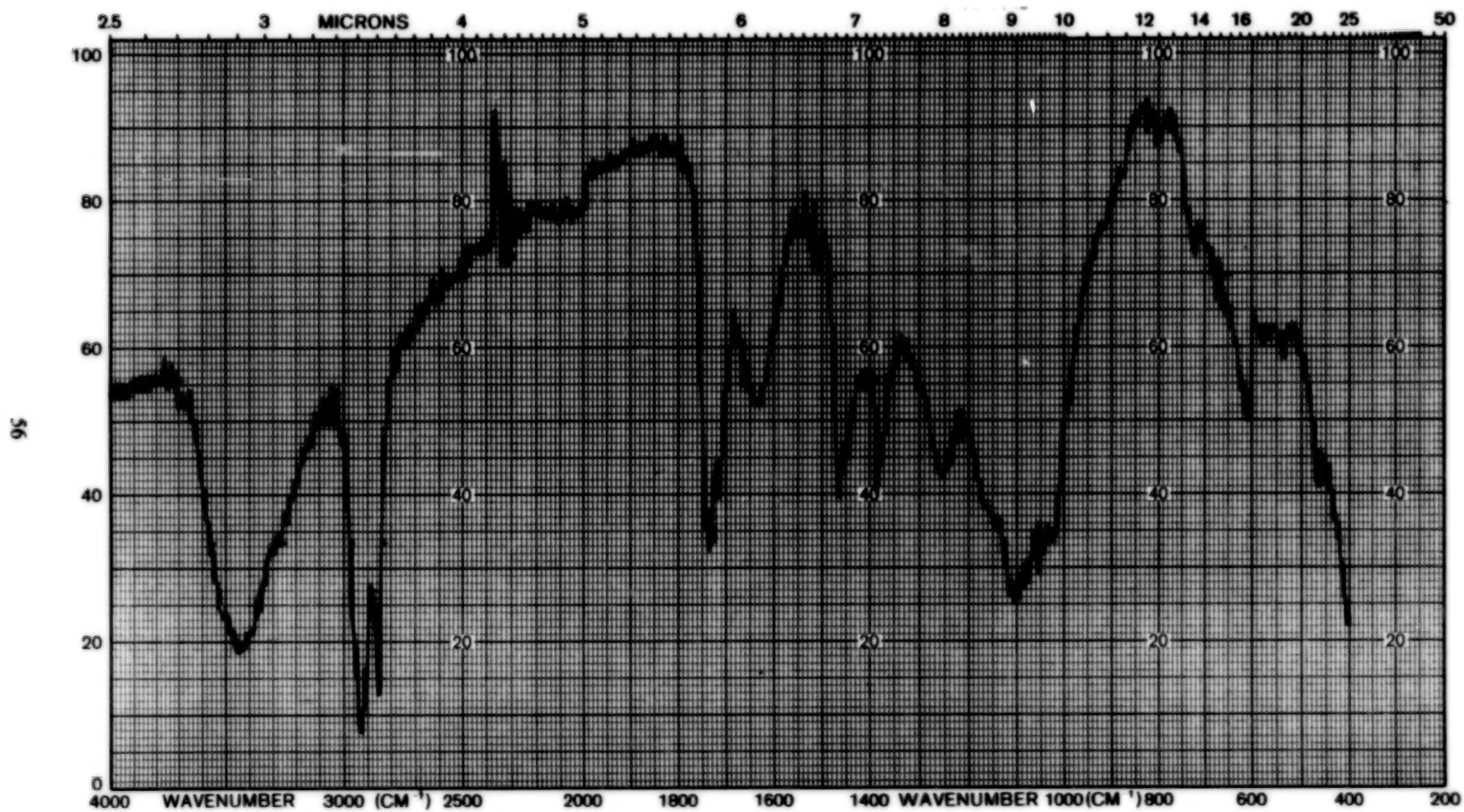


Figure 5. Typical infrared spectrum obtained from dry cold pressure fused toner—from Olympus Panoly E102 photocopier.

BLANK PAGE

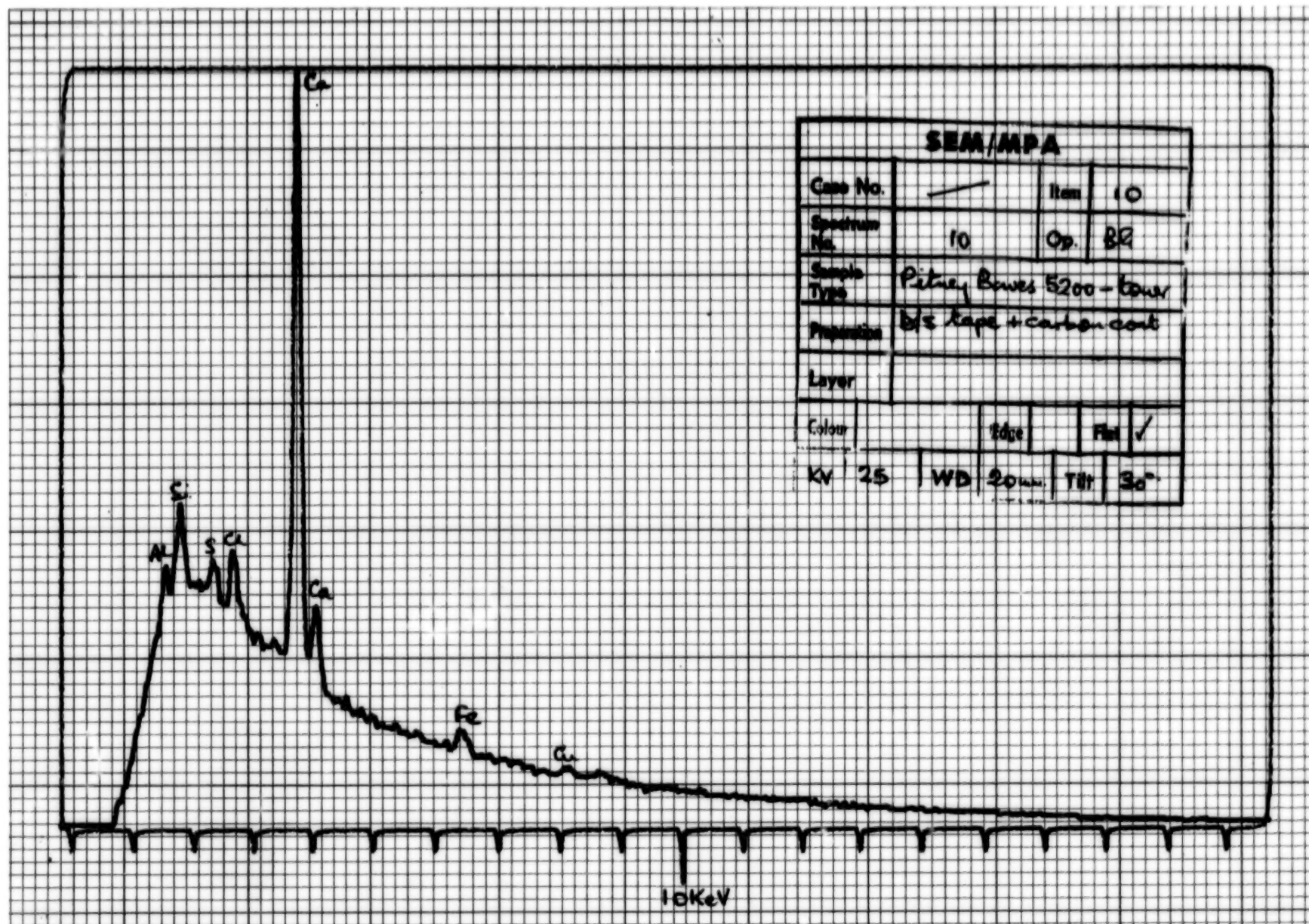


Figure 6. X-ray spectrum obtained from toner sample from Pitney-Bowes 5200 photocopier.

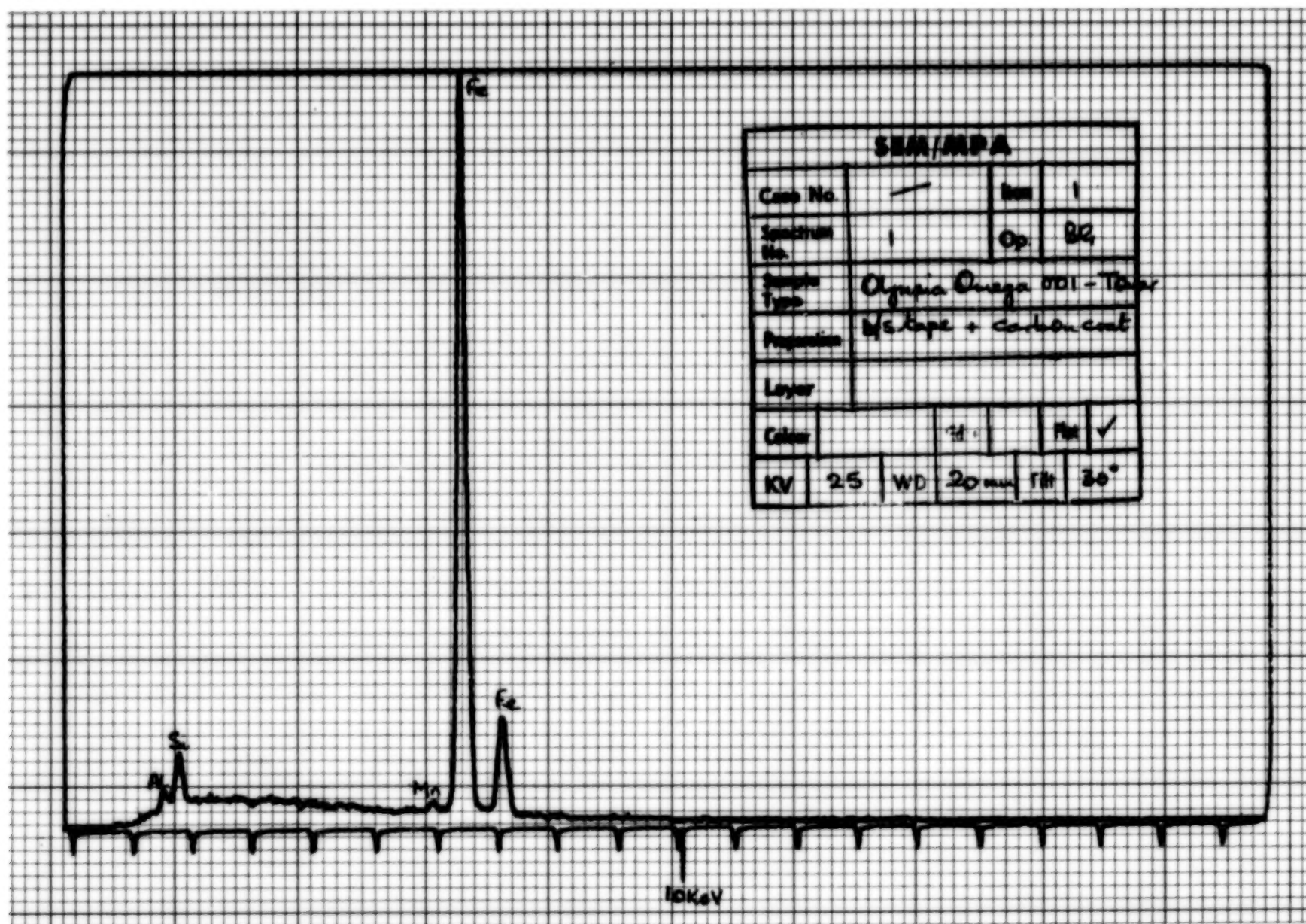


Figure 7. X-ray spectrum obtained from toner sample from Olympia Omega 001 photocopier.

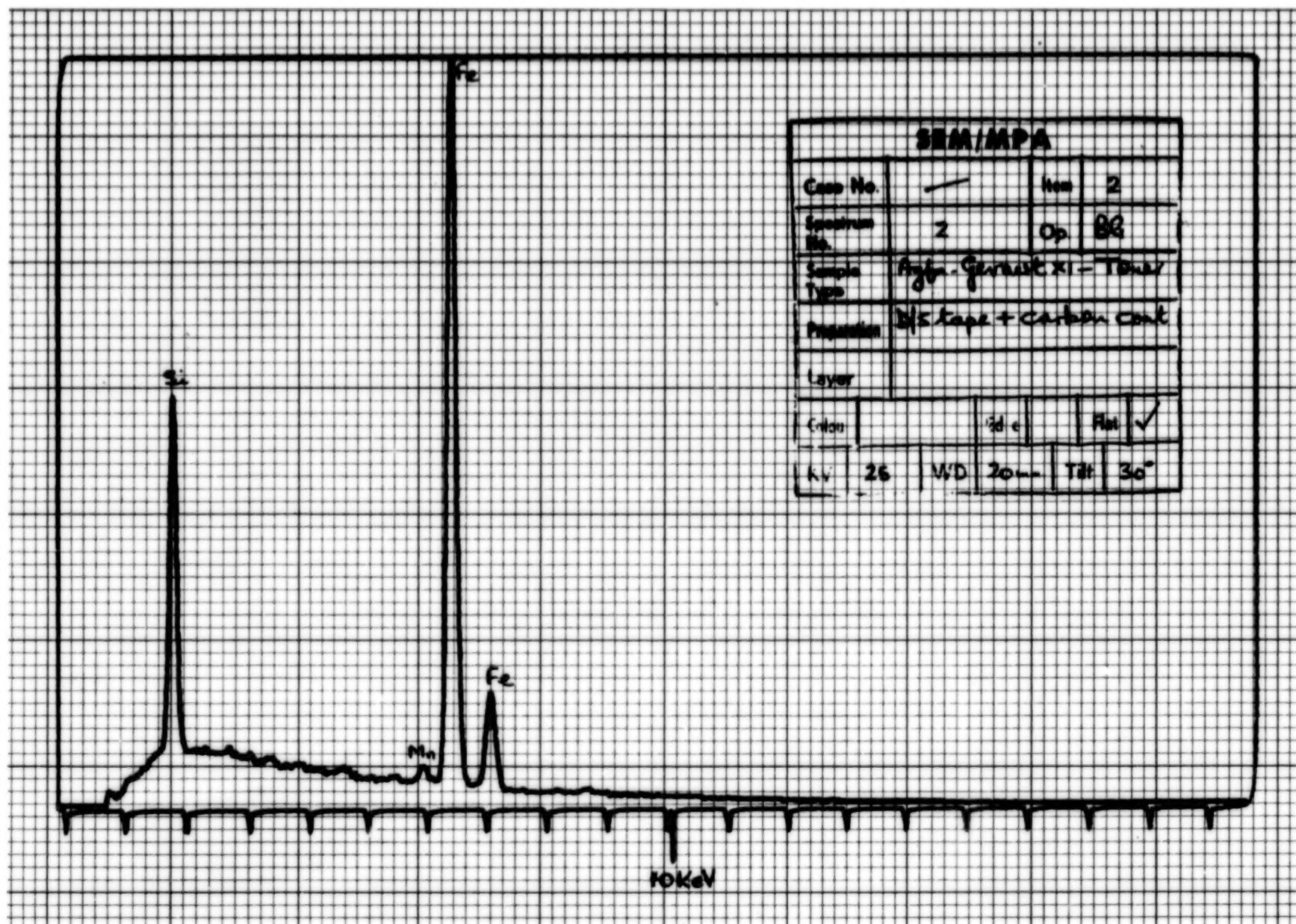


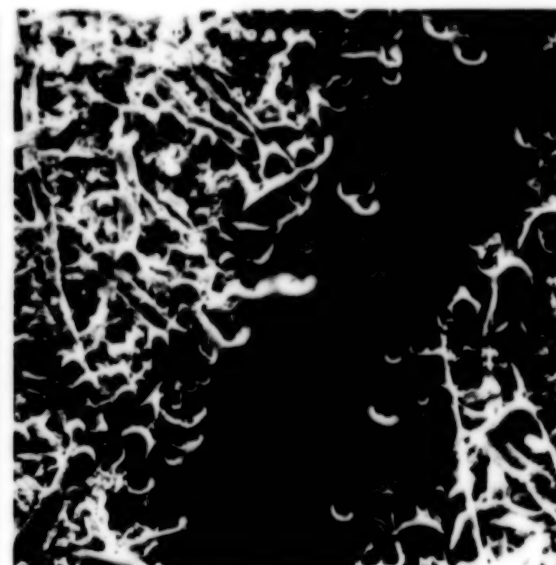
Figure 8. X-ray spectrum obtained from toner sample from Agfa-Gevaert X-1 photocopier.



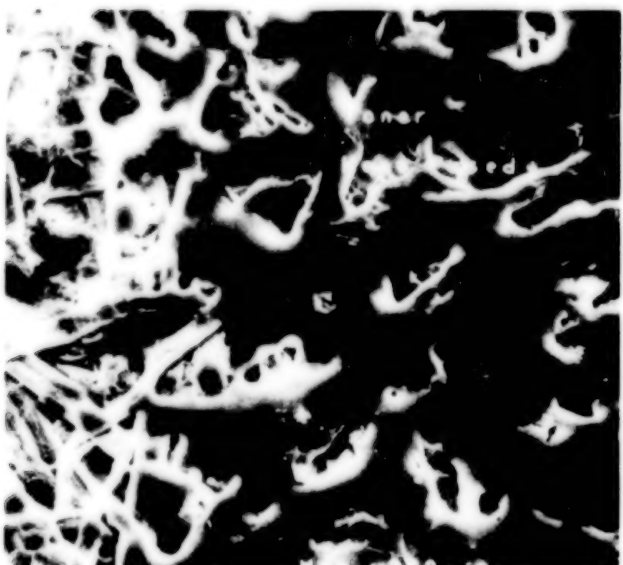
Toshiba BD727



Agfa-Gevaert X-10



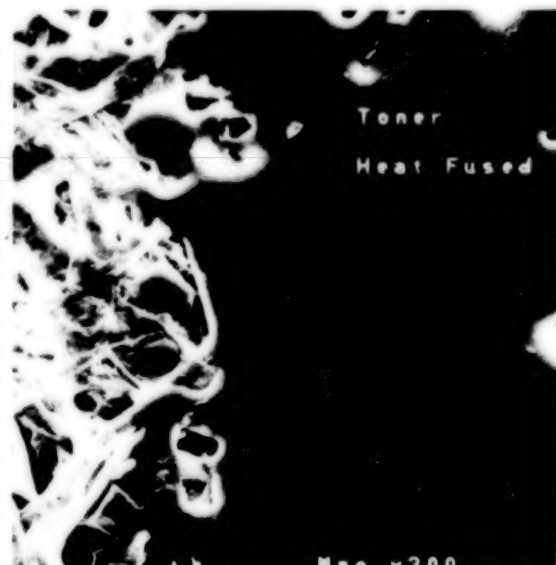
Xerox 2600



Xerox 3400



A.B. Dick 980



Olivetti Copia 1400 photocopiers

Figure 9. Variations in surface morphology of some dry photocopy toner deposits fused by heat as shown by scanning electron microscope photographs (magnified 200x). Toshiba BD727, Agfa-Gevaert X-10, Xerox 2600, Xerox 3400, A.B. Dick 980 and Olivetti Copia 1400 photocopiers.

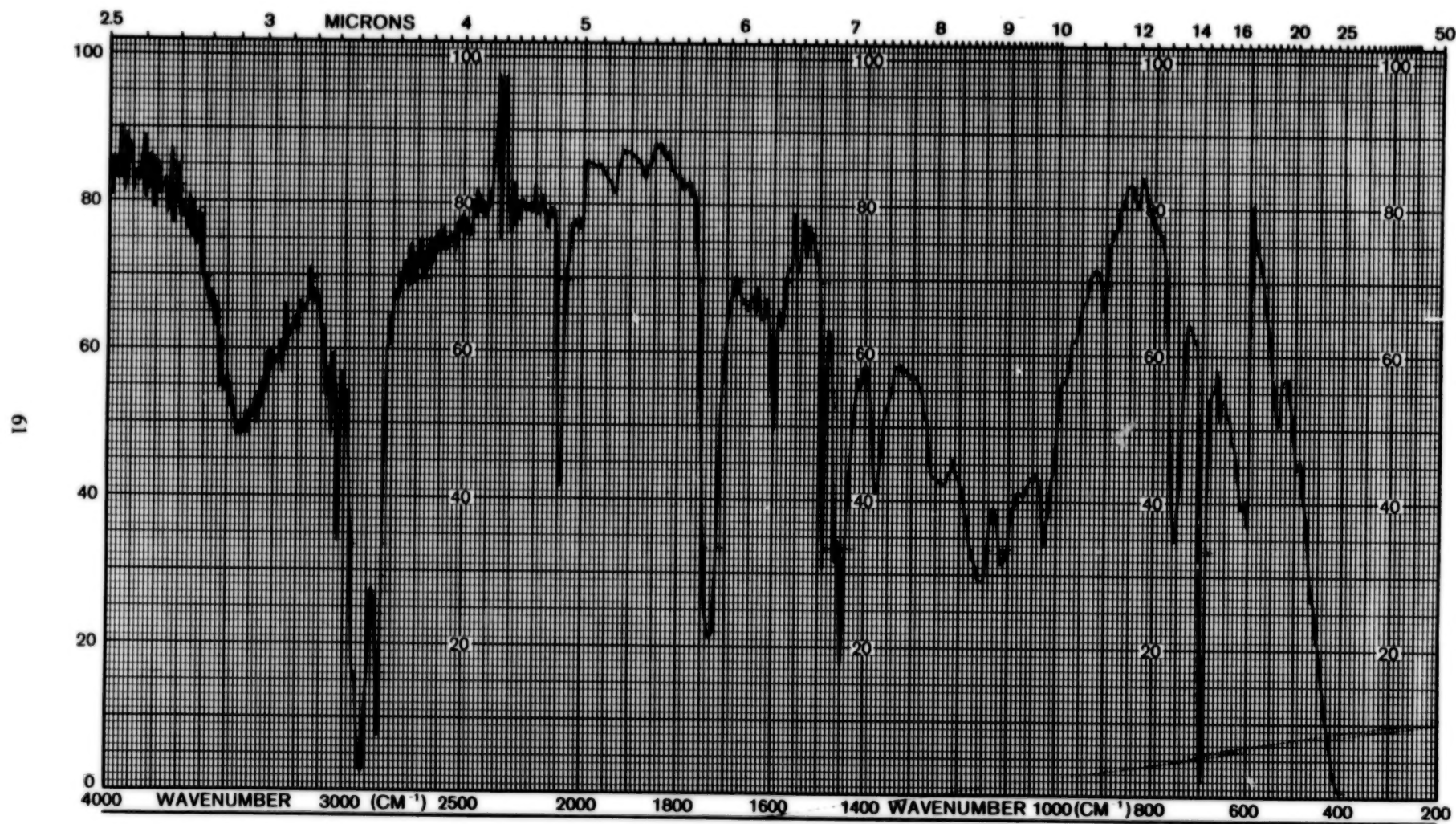


Figure 10. Infrared spectrum obtained from toner sample from Toshiba BD727 photocopier.

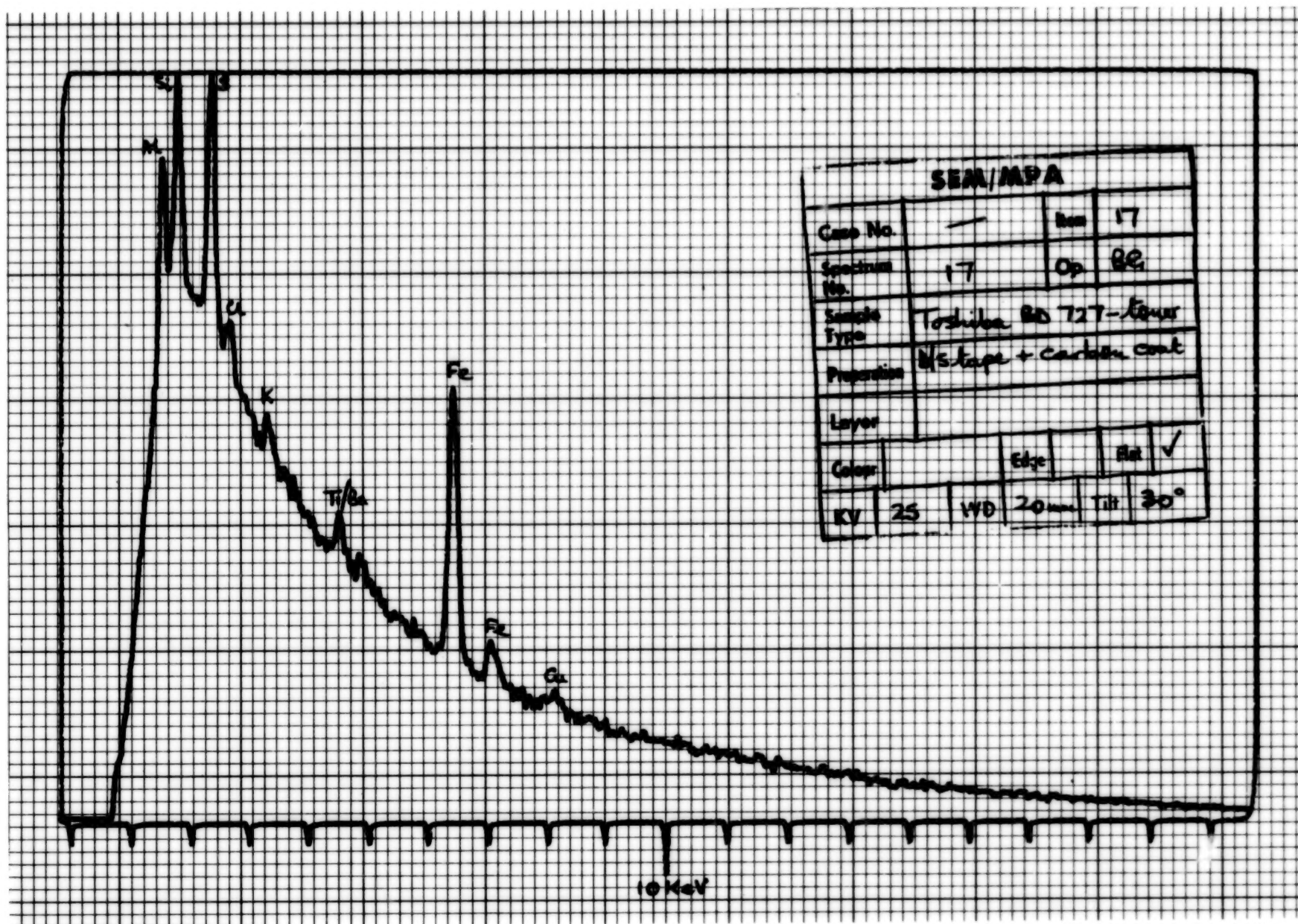


Figure 11. X-ray spectrum obtained from toner sample from Toshiba BD727 photocopier.

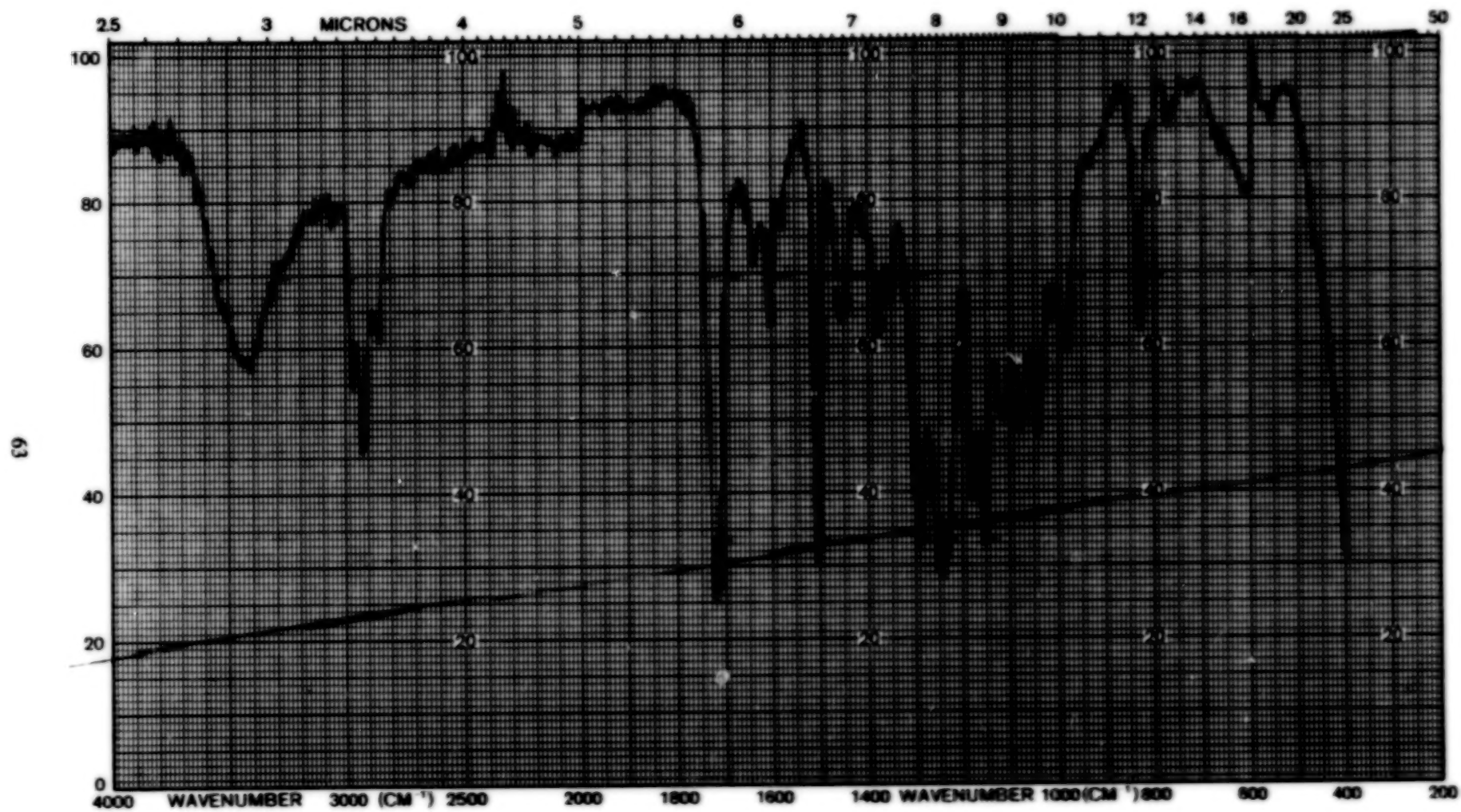


Figure 12. Infrared spectrum obtained from toner sample from Xerox 3450 photocopier.

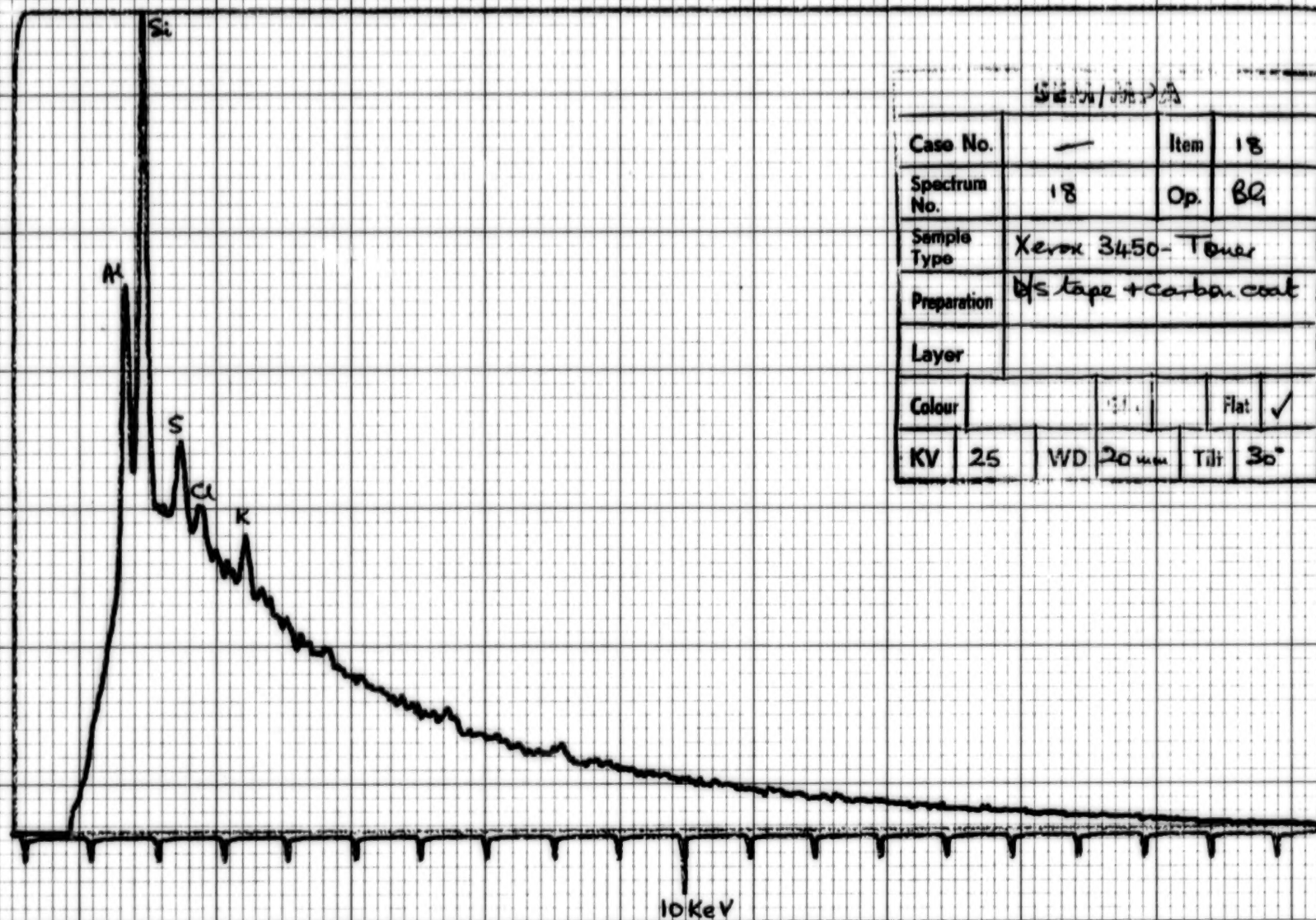


Figure 13. X-ray spectrum obtained from toner sample from Xerox-3450 photocopier.

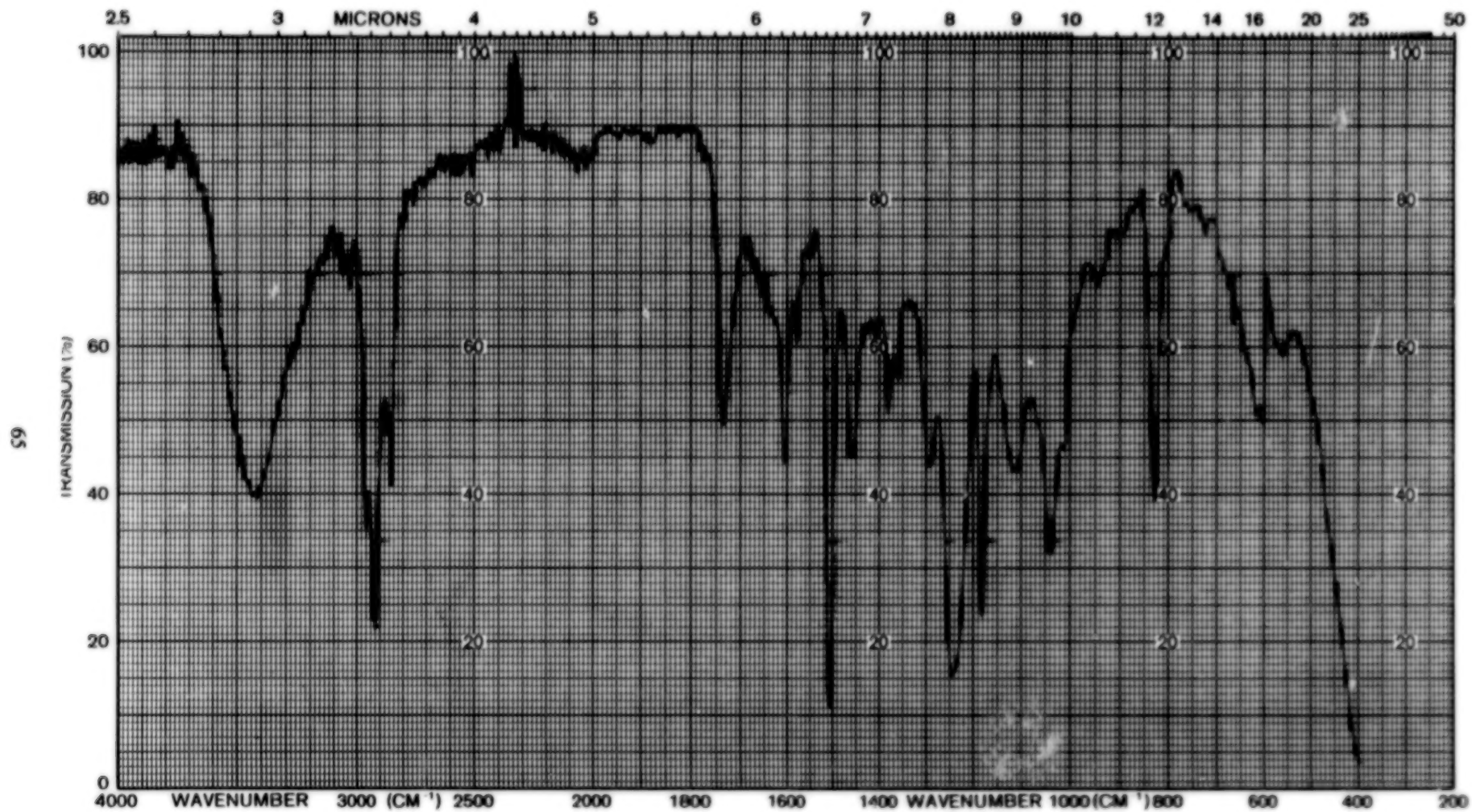


Figure 14. Infrared spectrum obtained from toner sample from Olivetti Copia 1400 photocopier.

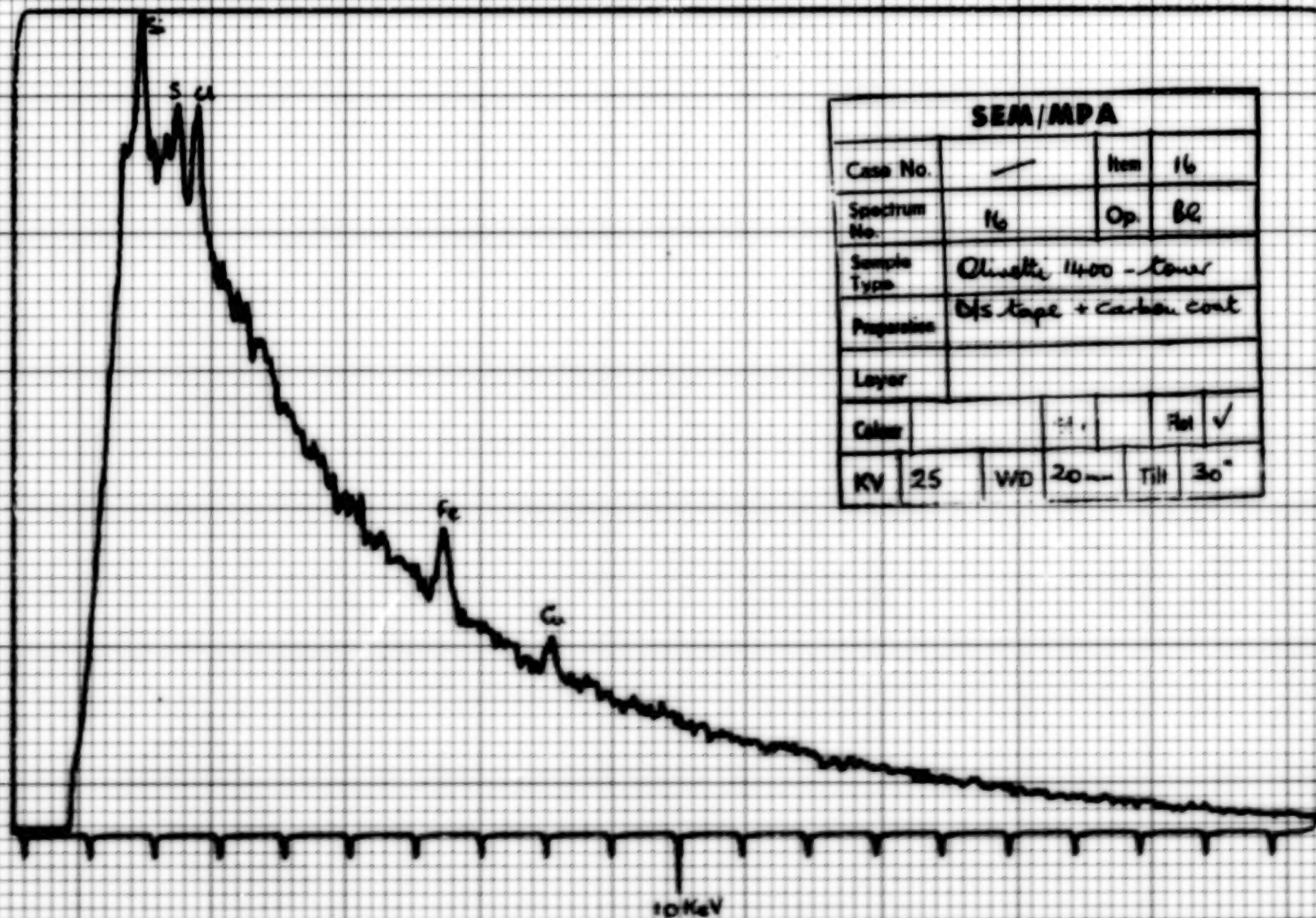


Figure 15. X-ray spectrum obtained from toner sample from Olivetti Copia 1400 photocopier.

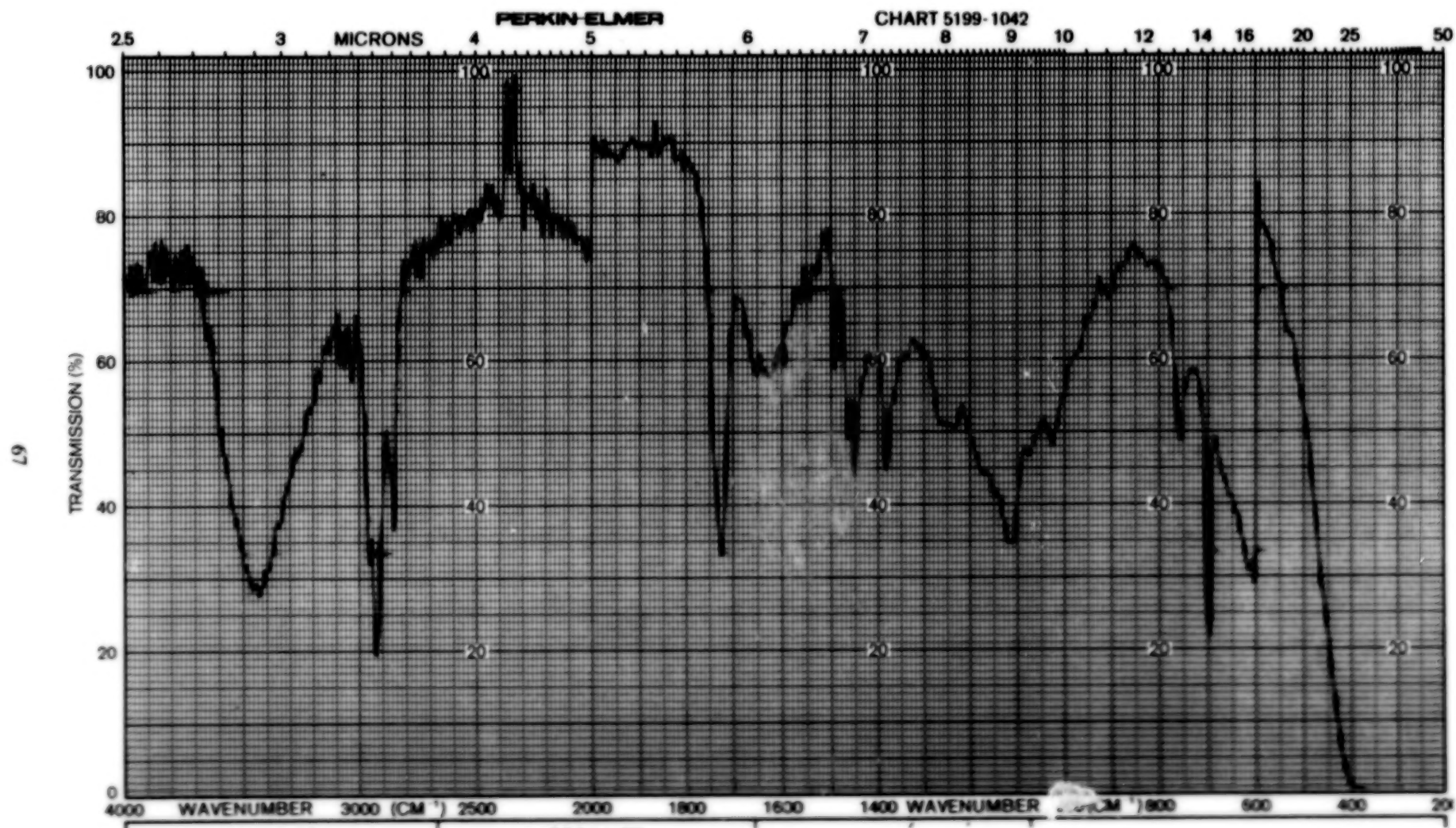


Figure 16. Infrared spectrum obtained from toser sample from Agfa-Gevaert X-10 photocopier.

reproducible and provide a simple method of distinguishing these visibly similar toners.

The X-ray spectra for these toners are also obtained with little difficulty and, provided paper background is taken into consideration, provide discrimination, although rather less than the infrared spectra.

DISCUSSION

The four methods reported here can all be used for the discrimination of toner material on photocopies.

The magnetic method is totally nondestructive but gives the least discrimination. Surface morphology can be examined nondestructively by high-power optical microscopy. These methods should be used as preliminary steps in an examination.

Examination of surface morphology using an SEM, which gives more discrimination than optical methods, and X-ray analysis, which also gives good discrimination, both require removal of paper from the document.

Infrared analysis of the toner requires removal of some material from the document and while not entirely nondestructive causes little damage. Discrimination between toner materials is good.

The four methods examine different aspects of the toner and provide different information. For full discrimination, all four methods should be used.

In practice, however, methods should be determined by what it is required to demonstrate or prove in each case. The purpose of this paper is to show what can be achieved from chemical and physical analysis of the toner, as part of a comprehensive approach to forensic photocopy examination.

It should be remembered that the photocopies discussed here are examples. Other types of toner have different surface morphologies and give different infrared and X-ray spectra, for example, those used in the many photocopyers that use combinations of heat and pressure fusing.

While experience has shown the value of our approach to photocopy examination, there are many other ways of approaching the same problems. In a recent case, for example, we were asked to determine the precise origin of a photocopy letter. The letter was known to have been produced on an island with a population approximately 60,000, a very high level of commercial activity and, therefore, a large number of photocopyers. The approach of the investigating team was to obtain samples of all photocopy papers supplied by paper wholesalers on the island. Twenty-seven different photocopy papers were submitted and compared with the questioned document.

Twenty six samples were eliminated on the basis of:

1. Sheet dimensions and thickness
2. Appearance and color in transmitted light
3. Appearance and color in ultraviolet light
4. Characterization of optical brighteners (fluorescent whitening agents).

Confirmation that the questioned document originated from the same source as the remaining sample was achieved after discussion with the manager of the paper mill involved. Confirmatory tests included:

1. Surface size alkalinity
2. Fiber analysis
3. Filler content.

The investigating team was then able to pursue the distribution of paper from the source for subsequent detailed examination of individual photocopier characteristics.

This approach offers a relatively quick and easy method of distinguishing photocopy papers, requires no expensive equipment and is thoroughly recommended.

This laboratory has been asked to examine photocopies from many points of view and for many purposes. Our approach is to know what can be done, to be aware of what information can be gained from each technique and to use the most effective and economical method to achieve the desired result.

EXPERIMENTAL

Infrared Spectrophotometry

Small amounts of toner were removed from the surface of the photocopy by gentle scraping with a scalpel blade, care being taken not to remove any paper fibers. The sample obtained was ground in an agate mortar with potassium bromide, a drop of chloroform or dichloromethane was added to assist mixing and the mixture was pressed into a 2 mm micro disc. The infrared spectra were recorded on a Perkin-Elmer 682 ratio recording spectrophotometer using a refracting beam condenser in the sample beam. The spectrophotometer was attached to a Perkin-Elmer 3600 data station, which was used for spectral manipulations.

Scanning Electron Microscopy

A small area of the photocopy toner was attached to an aluminum SEM stub using double-sided adhesive tape. The photocopy sample was gold-coated using a Polaron E-100 sputter coater. The morphology of the coated toner was examined in a Camscan Series 3-30 SEM with an accelerating voltage of 25kV, tilt angle 30° and a magnification of 200x.

Scanning Electron Microscope/Microprobe Analyzer

A small area of the photocopy was attached to an aluminum SEM stub and carbon coated using a Polaron E-5000/376 coater with carbon fiber evaporation attachment. The elemental content of the photocopy toners was determined using a Camscan Series 3-30 SEM fitted with a Kevex energy dispersive X-ray

detector and Link Systems 860 Series I multichannel analyzer. Instrumental conditions used were accelerating voltage 25kV, tilt angle 30°, 20 eV/channel counting for 4k counts in major channel at 2000 to 3000 cps.

REFERENCES

- Heuser, H. G. (1984).* Zur Untersuchung von elektrographischen kopierprodukten, KT-Material-Information 3:129-137.
- Kemp, G. S. and Totty, R. N. (1983).* The differentiation of toners used in photocopy processes by infrared spectroscopy, Forensic Sci. Int. 22:75-83.
- Warman, G. P., Curry, C. J. and Burke, P. (1984).* Evaluation of scanning electron microscopy with energy dispersive spectrometry for examining plain paper photocopies. Presented at: 10th Meeting of the International Association of Forensic Sciences, Oxford.
- Welch, J. (1985).* Magnetic aspects of printing, photocopies and bank cards, J. Forensic Sci. Soc. 25:343-347.
- Williams, R. (1983).* Analysis of photocopying toners by infrared spectroscopy, Forensic Sci. Int. 22:84-90.

SUGGESTED READING

- Holland, N. (1984).* Photocopy classification and identification, J. Forensic Sci. Soc. 24:23-42.

BLANK PAGE

QUESTIONED DOCUMENT EXAMINATION AS PART OF A COMPUTER CRIME INVESTIGATION

Craig L. Schlinz

FBI Laboratory

Washington, D.C.

Documentary evidence can play a significant role in a computer crime investigation. This paper discusses the various types of documentary evidence that may be of value during a computer crime investigation.

A large portion of the paper is devoted to computer-printed documents. Many of the modern computer printers are discussed, including printing defects that may develop and their possible causes.

DOCUMENTARY EVIDENCE AND THE COMPUTER CRIME INVESTIGATION

The most important evidentiary element of a computer crime investigation is documentary evidence. Computer documents account for approximately 80% of the physical evidence that an investigator will encounter (Schabeck 1980).

The majority of computer frauds are perpetrated by modification of computer input source documents such as vouchers, inventory transmittals, shipping slips and bank deposit slips (Bequai 1978).

In general, four ways to modify input source documents are:

1. Removal or omission of data
2. Addition of data
3. Alteration of data
4. Duplicate processing (processing a document more than once).

After the falsified or altered document has been prepared, it is either converted into some type of computer input medium, such as a punch card, paper tape or magnetic disk or tape, or the source document is read directly into the computer by an optical scanning process (Schabeck 1980).

One of the most common problems with any type of documentary evidence is determining the preparer. To determine the preparer of a questioned document, the following elements should be considered by both the investigator and the document examiner:

- (a) Document's origin
- (b) Contents
- (c) Circumstances of preparation
- (d) Determination of deletions, additions or other alterations of data
- (e) Age of the document
- (f) Source of the paper
- (g) Latent fingerprint
- (h) Handwriting
- (i) Typing/computer printers (Schabeck 1980).

The investigator must determine the importance of the questioned documents in the paper flow that resulted in the computer fraud. The investigator should also gather valid known documents that can be used as standards for comparison to the questioned documents. These standards should consist of handwriting/hand-printing exemplars from all suspects in the same wording and format as the questioned entries, typewriter/computer printer samples, identifying rubber stamps, exemplars from photocopiers and the type of paper. The questioned and known documents should be collected, cataloged, stored and then transmitted to the document examiner in such a manner as to preserve their integrity (Schabeck 1977).

PAPER EXAMINATION

Source document paper comes in all sizes, shapes, grades, weights and colors. The paper stock weight and grade varies depending on the use of the form. Optical character reader (OCR) forms are usually produced on heavier, quality stock with quality ink to ensure adequate clarity for the scanner. Vouchers, checks and stock certificates are usually printed on quality stock for durability and security and because these forms are usually read by an OCR scanning process.

A paper examination between a questioned source document and known paper exemplars can often determine whether the papers are similar in observable features or originated from different sources. Many source input documents, batch control tickets and program coding sheets are contained in padded form. Glue substance examinations, torn paper examinations or indenting examinations may produce valuable results.

The following physical characteristics and measurements differentiate paper: length, width, thickness, color, finish (such as bond, laid, smooth or glossy), opacity, reaction to ultraviolet and infrared light, watermarks, surface texture and reflectance and the relative position of cutter marks on the edges of the paper (Schabeck 1980).

Data processing systems make wide use of rubber stamps to indicate time and date received and sent by a department, the department name or code and various other types of control information. Many companies also stamp a document after it has been processed by the data entry (key-punch) department and by the computer operations department.

RUBBER STAMPS

Rubber stamps may be forged to resemble those used in normal operations. Comparisons should be made with known rubber stamp standards to determine if a different stamp is being used. If a known stamp is available for comparison purposes, and a sufficient number of unique identifiable characteristics, such as wear defects, are present, it may be possible for a questioned document examiner to positively identify the stamp as having prepared the questioned impressions. The type of ink used on the impression may also be important if differences are noted (Schabeck 1980).

PHOTOCOPYING

In many companies, photocopying of source documents is used as a standard practice where the original document is filed and the photocopied document becomes the in-house working copy. In some instances, the data processing department receives only the photocopy of the original document for processing through the system. This provides computer criminals with many opportunities to add, delete or alter data on the forms. Data can be erased, whitening fluid can cover data and new entries can be made to the document. The altered form is then rephotocopied and entered into the system paper flow. Through a side-by-side comparison with known photocopier standards, either taken by the investigator from a suspect machine or by using existing photocopied records, a document examiner may be able to positively associate a questioned photocopy with a known photocopier (Schabeck 1980).

HANDWRITING IDENTIFICATION

One of the most effective ways of proving authorship of a questioned document is handwriting identification. However, many questioned entries, such as a computer code or numerical entry, are so limited that they do not contain a sufficient quantity of unique handwriting characteristics to be identifiable. However, the investigator should not hesitate to submit questioned writings and known exemplars to a document examiner for comparisons (Schabeck 1980).

COMPUTER-PRINTED DOCUMENTS AS PART OF A COMPUTER CRIME INVESTIGATION

Almost every computer system has a printer connected to it for outputting information. Printers are available in a wide range of capabilities with print speeds ranging from 10 characters per second to more than 20,000 lines per minute. Printers may be electro-mechanical with many moving parts or electronic with a minimum of mechanical operations. Some printers

can print a full line of up to 160 characters at one time while others print one character at a time.

CLASSIFICATION OF PRINTERS

There are two primary classes of printers, the impact printer and the nonimpact printer (Schabeck 1977).

IMPACT PRINTERS

Impact printers fall into two basic classes, the character printer and the line printer. The speed of the character printer is measured by the number of characters printed per second, while the line printer is measured by the number of lines printed per minute (Winchester 1981).

Single-Element Printwheel Printer

Impact character printers can include devices used in small word processing systems such as single-element typewriters with a ball element and printwheel typewriters with the daisy-shaped element.

Both single and printwheel elements can be molded out of plastic. The characters are generally electroplated to add durability. Small fragments of plastic or dust particles often adhere to the surface of characters prior to the electroplating process and result in random manufacturing defects on the typeface. Microscopic examination of a known element may identify some of these randomly placed raised beads. These defects may cause printing defects in the questioned typing.

Printwheel characters are impacted against the ribbon and the paper by a hammer directly behind the character when located in the print position. The adjustment of the hammer strike intensity is quite critical. If the hammer applies too much pressure, it may break the character spoke and render the printwheel useless. A broken spoke results in the hammer directly striking the ribbon and leaving a black smudge in place of a desired printed character. A review of the wording of the text will indicate which character has been broken off.

Printwheels and single elements are interchangeable and an examination of the questioned typed material may identify only the element and not the printer used to prepare the document.

A variation of the printwheel is thimble shaped as opposed to the more common daisy shape. The thimble element is used with such systems as the NEC Spinwriter printer.

The characters on a printwheel and single element will eventually show wear through use. The spokes on a print wheel may become twisted, resulting in lateral misalignment of the printed character.

The electroplating on the characters of a metal print-wheel will begin to peel after extended use. This is believed to be caused by deterioration of the underlying nonmetal material from repeated hammering of the character (Leslie and Stimpson, personal communication).

When an examination determines that the type styles are consistent and that a sufficient number of typeface defects and alignment characteristics are present, it is possible to identify a specific element that prepared a questioned typing. However, it will probably be necessary for the investigator to submit both known typewriter exemplars and the original typing element to the document examiner for examination to obtain a definite conclusion.

Drum Printer

The drum printer is an impact line printer. It consists of a steel drum that spins on a horizontal axis. On the outer surface of the drum are 132 vertical columns of raised characters across the length of the drum. Each column contains a complete character set of up to 64 characters. Parallel to the drum is a hammer bank, which consists of one hammer for each of the 132 separate columns of the drum.

The paper and inked cloth ribbon run between the hammer banks and the rotating drum. The paper is advanced by means of spoked wheels called tractors. The individual hammers strike the paper against a character on the rotating drum at the instant the character is in the print position, leaving an impression on the paper. The drum revolves clockwise at speeds exceeding 1,800 revolutions per minute. It is, therefore, imperative that the hammer strike at the exact instant the character on the drum is aligned with the hammer. A timing difference or a misalignment between the hammer and character results in an imperfect character impression on the paper (Leslie and Stimpson, personal communication).

The following is a list of possible printing defects often observed in drum printer printouts and their possible sources:

1. Character printing low: When a hammer strike mechanism is delayed, all the printed characters in the column corresponding to that particular hammer will print low in comparison to the other characters in the line. As this delay becomes greater, the defective impression becomes more obvious until the lower portion of the character is eventually cut off. When this delay is even longer, the character impression is cut off and a partial impression of the next step character becomes visible above the cutoff character impression.

2. Character printing high: When a hammer strike is premature, all the characters in the column corresponding to that particular hammer will print high in relation to the other characters in the line.

3. Uneven (off-the-foot) impression: Each hammer in the hammer bank has some lateral play, which can result in misalignment. If a particular hammer becomes

misaligned, it will not strike the characters on the drum evenly, resulting in an off-the-foot impression. This means that the character will print heavier on the right or left side, depending on which direction the misalignment occurs. A severely misaligned hammer may result in a partial impression of the character. If the hammer is so severely misaligned that it partially strikes the character in the adjacent column, a partial impression (ghosting) of the character will result. The misaligned hammer may cause the adjacent hammer to be dragged forward by the motion of the hammer in the print position, causing the second hammer to strike the subsequent lateral character.

4. Light impressions: After long-term use, the most frequently used characters may begin to wear down. The resulting impression will be less intense, surrounded by a vague outline of the hammer face.

5. Misalignment of a whole line: The paper in a drum printer is advanced by means of two sets of tractors situated on each side of the printer. The perforations along the edges of the paper are threaded into these tractors. If the tractors are not perfectly aligned, the printed line will not be parallel to the lined paper. The examiner should ensure that the lines on the paper are not themselves misaligned.

6. Dark to light (or vice versa) printing across a sheet of paper: This could be caused by the cloth ribbon being worn only on one side. This uneven wear is often caused by printing using a set number of lateral columns. This characteristic has very limited value. The uneven inking is usually caused by an uneven bearing of the hammer bank in relation to the drum.

Smudging of characters on the paper caused by a dirty character drum should not be confused with worn characters. Worn characters are rare and are usually surrounded by the outline of the print hammer. Smudging of characters is more frequent and the hammer outline surrounding the character is not as distinct (Leslie and Stimpson, personal communication; Winchester 1978).

Train or Chain Printer

Chain printers, or train printers as they are sometimes called, are impact line printers containing a chain made of character slugs. The chain surrounds a drive wheel and one idler gear mounted on the same plane. A turning of these wheels advances the chain, carrying the characters past 132 print positions. The chain of slugs travels horizontally. There is usually one hammer for each of up to 132 print positions. When a character passes a selected print position, a hammer mounted in the hammer bank strikes the paper against the ribbon and slug to produce the impression. Since the chain travels horizontally, a single letter could be impressed on all 132 columns or print positions.

As with the drum printer, the timing of the hammer strike against the character is critical. Any malfunction of the hammers, revolving train or the interaction

between the two results in a defective impression on the paper.

Horizontal misalignments down a column of printing are evidence of a chain or train printing device. When viewed down one column, this characteristic appears as a wavy line of print. Several probable causes for this defect are as follows:

1. There is a small-gauged space between each slug on the chain. After extended use, this gap may vary along some portions of the chain because of a build-up of dirt between the slugs or crowding or jamming somewhere along the train. This results in all the characters on one slug passing by the striking hammers slightly early or late depending on the degree of space between the slugs. If the space is excessive a partial impression will be the result.

2. A break in a character slug at the spot where it is attached to the chain may result in erratic spacing along the chain. This causes jamming of characters along the train, especially as the broken slug rounds the drive wheel or idler gear.

3. By design, there is a certain amount of play between each hammer in the hammer bank. When the hammers are properly adjusted, they print the characters so that they appear evenly spaced. When the space between two adjacent hammers increases from wear in the comb that aligns each hammer, the result is an excessively wide space between the two printed columns. This increase in space between two hammers will cause a corresponding decrease in space between the misaligned hammer and its other adjacent hammer, resulting in crowding between the two printed columns.

4. A delayed hammer strike will also result in misaligned columns.

5. Ghosting, as previously discussed, is the joint impression of a second character appearing immediately before or after the impression of the intended character. This is caused by either a premature or late strike of a hammer or by the striking hammer dragging an adjacent hammer partially into the print position.

6. Cutoff left or cutoff right impressions are also due to early or late hammer strikes that do not result in complete contact with the characters.

Worn characters result in indistinct impressions (Leslie and Stimpson, personal communication; Winchester 1978).

Dot Matrix Printer

Another type of impact printer is the dot matrix printer. The printhead has an array of small pins that are independently propelled against an inked ribbon, transferring dots onto the paper behind them. Each pin is activated by an electromagnetic field controlled by the printhead's control electronics. Depending on control codes, one or more pins of the array can be activated at the same time, producing a single dot or a pattern of dots aligned vertically (Mello-Grand 1984). The column of pins then moves horizontally to the next print position in the character matrix and continues

to strike the paper in this lateral movement until all horizontal (five or seven) print positions for a character have been completed (Leslie and Stimpson, personal communication).

Older and less expensive dot matrix printers use a seven-pin, one-line array to generate characters from a 5 x 7 dot matrix. Each character is formed from a pattern of dots in a cell, which is 5 dots wide and 7 dots high. The combinations of dot patterns available in such a small matrix are very limited. For instance, a 5 x 7 matrix doesn't provide descenders, forcing lower case letters such as *g*, *j*, *p*, *q*, and *y* into nonconventional shapes.

Nearly all modern dot matrix printers use a nine-pin in-line array to form characters from a 7 x 9 matrix. The additional pins allow moderation of true descenders and a closer approximation of traditional characters. The print quality is also improved by the denser pattern of dots whose individual boundaries are less visible than those from a 5 x 7 matrix (Mello-Grand 1984).

Print defects can usually be attributed to printhead malfunctions. The following are printing defects encountered in dot matrix printed documents:

1. Gaps in the printed characters are caused by a failure of the printhead pins to strike the paper through the inked ribbon. This is a result of broken pins or a malfunction of the wire actuating mechanism.

2. Matrix characters printing heavy on the top and light on the bottom or vice versa are attributable to an improper plate and printhead alignment.

3. Differences in intensity in the ink dots made by different pins in the matrix cause a striped effect in the characters with light and dark stripes running horizontally across the page, corresponding to specific pins. This characteristic is related to impact differences among the printhead pins.

4. Light impressions that occasionally occur throughout the printout are caused by sporadic binding of the pins in the printhead. This prevents the pin from impacting the paper as forcefully as it does under normal conditions (Leslie and Stimpson, personal communication).

Key Punch Machines

Research conducted by Clifford E. Curvey and Claude E. Eaton on IBM keypunch machine printouts concluded that the printouts were identifiable with the machines. In their research, it was determined that standards from 100 different machines could be differentiated (Curvey and Eaton 1976).

Printing is performed on the IBM key-punch machines through a dot matrix printhead. One character at a time is printed across the top of the punch card in the same column that the machine is punching. The printing and punching are performed simultaneously. The printer unit may be turned off, with only punching being performed. However, any character printed must also be punched.

As with any dot matrix printer, the characters are comprised of a series of dots. Key-punch printers develop many individual characteristics, which are defects such as missing, misaligned or extra dots. The research determined that the printed product of each machine is highly individual and readily distinguishable by a document examiner.

The most common characteristic is the misalignment of the individual dots. Lines that should be straight are not. Another significant characteristic is the spacing between dots (Curvey and Eaton 1976).

Missing dots are another common characteristic found in dot matrix characters. This problem is caused by a bent print wire or a broken code plate projection. The code plate contains projections that transmit pressure to the print wires. The code plate is located between a pressure plate, which provides the pressure on the code plate to cause the printing, and a return plate, which pulls the wires back after the printing is accomplished. If the same wire does not print in all characters, the problem is caused by a bent wire. However, if the wire does not print in one character and prints in others, it is the result of a broken code plate projection.

Since each printhead contains 35 individual wires, minute changes occur and are excellent for dating questioned items. It is necessary to have an adequate number of standards covering an extended period of time. Such standards are generally readily available since most key-punch machines are in continuous use (Curvey and Eaton 1976).

NONIMPACT PRINTERS

Nonimpact printers do not use print hammers for letter and ink impressions. Some examples of nonimpact printers include the thermal matrix printer, ink jet printer, laser printer and the plotter.

Thermal Matrix Printer

The thermal matrix printer uses a matrix printhead that generally consists of five columns and seven rows of tiny heat elements. The printhead moves across heat-sensitive paper, and at each print position (5 x 7 matrix) selected elements are electrically heated. The heated elements produce an image on the paper as the printed character. A number of malfunctions may occur in this printer; however, many of them are so severe that the printer becomes inoperable.

Most observable defects in the printing can be attributed to the printhead. The printhead is made of three main components, the circuit module, the wire band and the dot matrix. A malfunction of the circuit module, breaks in the wire band or burned-out matrix elements result in portions of the matrix consistently not recording.

Unequal power supply to the various heating elements in the matrix causes some elements to become

hotter than other elements and are recorded on paper as darker spots or impressions than those elements receiving less current.

A distinct line impression above the line of print is caused by a misalignment of the printhead to the paper (Leslie and Stimpson, personal communication).

Laser Printer

In a general sense, the laser printer operates on principles similar to a bond paper electrostatic photocopier. A large drum covered with a flexible photoconducting material rotates at a constant speed. A laser beam is focused to a tiny spot, which is scanned repeatedly across the length of the drum. The image is created by the same process used in a photocopier.

Prior to being exposed to the laser beam, the drum is given an electrostatic charge over its entire surface. The laser beam disperses the charge because light causes one of the layers coated on the drum to become electrically conductive. The areas not exposed by the laser beam form the actual image. These charged areas attract the toner, which is then transferred to paper to form the printed page in the same way a photocopier image is transferred to paper.

Laser printers actually write in a dot matrix format. However, they are capable of dot densities of 180 to 480 dots per inch. This high resolution allows the printers to write in practically any type style and produces excellent graphics.

Upon close inspection with magnification, laser-printed documents exhibit two distinct characteristics: (1) the scattering of random toner particles around various letters, and (2) the jagged or wavy appearance of diagonally constructed letters (Truman 1983).

If the surface of the photoconductor drum is scratched, marks are transferred to the paper on each rotation of the drum. The scratch may be eliminated by advancing the roll of photosensitive material that circumscribes the drum. Therefore, it is imperative that known specimens be obtained as close as possible to any questioned text to permit a meaningful comparison.

Print quality problems can be caused by such problems as a defective laser mirror motor (Leslie and Stimpson, personal communication).

Ink Jet Printers

Ink jet printers are nonimpact printers that create the printed characters by propelling droplets of ink onto the paper. There are two common ink jet techniques. Continuous stream printheads dispense an uninterrupted stream of ink droplets that are electrically charged to varying degrees. The electrically charged drops are deflected vertically by two electrostatic plates. Uncharged droplets are intercepted by a gutter and the ink is recycled into the ink jet. The jet scans the paper horizontally at a constant speed. Drops are deposited in appropriate positions to form the character. Each

character is printed within a character matrix 40 drops high and 12 to 28 drops wide, according to the pitch and typestyle used.

The second type is called a drop on demand printer, which ejects single ink drops as needed. The drop on demand printer also shows promise as a color printer (Freedman 1983).

The resultant characters of ink jet printers have a slight dot matrix appearance under magnification and a jagged or wavy appearance of diagonally constructed letters.

The print quality depends on the accuracy with which the individual dots are placed on the paper. Vertical placement errors are primarily caused by the ink jet system and horizontal errors by printhead velocity variations. Dot placement errors fall into two general classes: errors that affect all dots uniformly, which cause size variations either in the height or width of the character being printed, and errors that affect placement of individual dots relative to neighboring dots.

A misplacement of dots relative to adjacent drops can cause raggedness of the edges, voids and a loss of optical density. When splitting in the characters occurs, the most probable causes are (1) an off-center charge electrode, (2) a crystal in need of adjustment or (3) increased drop spacing.

Any appreciable change in the print quality of an ink jet printer is likely to be noticeable and technical adjustments are generally made fairly quickly. Therefore, it is necessary that known standards produced at a time as close as possible to any questioned text and before technical adjustments, be made available for comparison purposes (Leslie and Stimpson, personal communication).

New Technology

Much research and development is being conducted in the nonimpact printing field. One new system that is currently being marketed by the Ferix Corporation of Fremont, California, uses magnetic printing technology. The technology centers on a newly developed thin film magnetic head, developed by the Ferix Corporation. The head has a 16 x 18 array of magnetic head elements. These elements transfer their magnetic flux through the head substrate onto an oxide-coated drum.

The Ferix page printer images three lines of print on each revolution of the drum. When the image is complete, the drum receives dry toner. Paper is then passed against the drum and the electrostatically charged toner is transferred to the paper. The paper then passes through a fuser where the toner is fused to the surface.

The magnetic heads transfer the image to the drum surface and the image remains on the drum until it is erased. Any number of copies can then be printed from the drum without having to transfer the image to the drum for each copy. This increases the speed of copying. The Ferix office page printer can print 10 pages per minute as duplicates (Romei 1985).

Another newcomer in the nonimpact printing field is the ion deposition technology. This technology also seems to show promise as a major challenger to xerography and laser xerography in the high-speed printing class. Ion deposition requires only four mechanical steps instead of the six now required. The printer, therefore, has 75% fewer parts. The drum has a dielectric rather than a photoconductive surface, which makes it more durable, and current testing indicates that it has required service calls just once per 200,000 copies (Williams 1984).

Further research must be performed to determine characteristics that may differentiate the high-speed nonimpact printing methods and to determine if the printer produces unique identifiable characteristics.

CONCLUSION

Both input and output documents are an important element of computer crime investigations. A forensic document examination can provide valuable evidence in these investigations.

The document examination may, in many instances, only produce class evidence, placing the document in a class of documents such as a type of paper, printer or photocopier. However, if a sufficient number of unique identifiable characteristics are present, positive identifications may be possible. These include handwriting identifications, indented writing, establishing that two documents were in contact with each other or that a document was positively produced on a known printer. Therefore, investigators should always consider submitting computer crime documents to a qualified document examiner for examination.

REFERENCES

- Bequai, A. (1978).* Computer Crime, D. C. Heath and Co., Lexington, Mass.
- Curvey, C. E. and Eaton, C. E. (1976).* Identification of IBM key punch machines by their printed products. Presented at: 28th Annual Meeting of American Academy of Forensic Sciences.
- Freedman, D. (1983).* Inkjets aim at color printing, High Technology, October.
- Mello-Grand, S. (1984).* The art of benchmarking printers, Byte Publications, February.
- Romei, L. K. (ed.) (1985).* Printing partners in processing, Modern Office Technology, May, pp. 80-88.
- Schabeck, T. A. (1977).* Computer crime investigation, Assets Protection, Vol. 2.
- Schabeck, T. A. (1980).* Computer Crime Investigation Manual, Assets Protection, San Francisco, Calif.
- Truman, V. R. (1983).* Laser Printing. Presented at: The 41st Annual Conference of the American Society of Questioned Document Examiners.

Williams, T. (ed.) (1984). Magnetic printing technology, Computer Design, October, pp. 44-47.

Winchester, J. M. (1981). Computer-printed documents as part of a computer crime investigation, J. Forensic Sci. 26:730-738.

Winchester, J. M. (1978). Computer print quality defects: Significance for the document examiner. Presented at: The 8th International Association of

the American Society of Questioned Document Examiners Annual Meeting.

SUGGESTED READING

Hecht, J. (1984). Printing with speed of light, Computers and Electronics, April, pp. 73-75.

BLANK PAGE

LABORATORY SUPPORT IN COUNTERFEITING INVESTIGATIONS

John W. Piper

U.S. Secret Service
Washington, D.C.

In 1865, the U.S. Secret Service was established for the purpose of suppressing counterfeiting. At that time one-third of all the currency in circulation was counterfeit and posed an eminent threat to our national security. To compound this problem, currency was issued by more than 300 different institutions, each having its own design. The public had to be familiar with each of these currencies. This provided an excellent environment for counterfeiting.

After the establishment of the U.S. Secret Service, all counterfeit investigations were coordinated on a national level. Shortly thereafter, a standard was established for U.S. currency, and counterfeiting was brought under control.

Counterfeiting remained dormant until the Depression. During this period, counterfeiting skyrocketed. This trend continued for only 4 years, which corresponds to the end of that era.

During World War II (1942 to 1946) counterfeit activity dropped to an all-time low, but within a year after the end of the war counterfeit activity made a sharp upward swing. This trend was probably caused by the increased development, availability and popularity of offset printing equipment. This trend continued, but in 1950 the trend reversed and continued that way for 6 years, corresponding to the Korean War.

Since 1956, this counterfeiting trend has steadily increased with fluctuations caused by periods of economic recession. Today's counterfeiters produce \$90 million every year—\$8 million of which will be successfully passed to the public. Approximately 90 printing plants are suppressed each year and 1,800 people are arrested.

Since we, as forensic scientists, have no control over economic fluctuations, we should be aware of potential changes in printing that will influence types of counterfeits we will be examining. For example, 99% of all the counterfeits manufactured are produced by the offset method. We expect this trend to continue for at least 5 to 10 years. However, we have already seen a dramatic increase in the use of office machine copiers and we expect this to continue.

With expansion of the personal computer industry, there is also developing a demand for an inexpensive color printer. Currently, color ink jet printers that offer 80 dots per inch resolution are available for \$800. As technology progresses we will certainly see more documents with higher resolution produced on this type of printer.

Computers and lasers are increasingly being used in electronic publishing and in the production of four-color separation negatives. As genuine documents become more sophisticated in their design, it will be

necessary to use this high technology to deter counterfeiting. Recently Great Britain, which produces a multicolored currency, has been hit hard with counterfeit 20 and 50 pound notes produced with a laser scanner.

In 1984, Congress passed legislation giving the Secret Service shared enforcement authority in the counterfeiting and/or fraudulent use of credit cards. The June 1985 edition of "The Nilsen Report," a credit card industry publication, states that on an average day 10,247 cards are lost or stolen. The credit card industry will lose a total of \$3.98 billion, \$716.4 million to fraud. Every fraudulent card represents an average loss of \$790 to the industry.

Since jurisdictional acquisition, the Secret Service has arrested 240 individuals for credit card counterfeiting and/or fraud and has seized, prior to circulation, 26,000 counterfeit credit cards. The counterfeit plants suppressed so far represent an estimated production and distribution potential of more than 500,000 additional cards.

Association of Counterfeit U.S. Currency Through Laboratory Analysis

Significant investigative value is derived through laboratory association of individual counterfeit notes. With this association we can consolidate our investigative leads and focus our efforts on the respective counterfeit operation.

To accomplish this task, in 1865 the U.S. Secret Service established a specimen file of all known counterfeit obligations of the United States and many foreign governments. As new counterfeits appear they are systematically compared to the specimen file to determine if an association can be made. Through a circularization system, which is based on printing plate defects, the distribution paths of counterfeit currency can be established. Through this process, more than 60% of the new counterfeit notes that are not of record are associated to known counterfeit operations.

In virtually all counterfeiting operations it is first necessary to capture the image of a genuine Federal Reserve note. This particular genuine note is called the pattern note. In most counterfeiting processes, this image is captured photographically and produces high-contrast negatives. These negatives are used to produce printing plates that then produce the counterfeits.

Every genuine note or pattern note possesses individual characteristics, such as a random security fiber pattern in the paper, intaglio ink bleeding and letterpress ink irregularities. During these photographic processes these individual characteristics will be cap-

tured and reproduced in the negative of the counterfeit. In addition, many more characteristics may develop in the negative from cracks, scratches or touch-ups with opaquing paint. As we might suspect, these characteristics will be transferred in the platemaking process and will reproduce on all counterfeit notes that are printed from that plate.

To counterfeit U.S. currency, a minimum of three printing plates are required: one for the back of the note and two for the front, which will be used to print the black and green inks.

Some counterfeiters will produce additional plates in order to change the serial numbers, series years, plate numbers and Federal Reserve Bank seals. Other counterfeiters will produce many plates with different descriptions and change the combination of front plates with back plates to produce a variety of notes. In both cases, the counterfeiters will use the same basic plates to produce notes with different descriptions.

Office Machine Copiers

In the past few years we have seen a dramatic increase in the use of office machine copiers (OMCs) to produce counterfeit currency and other documents. In fiscal year 1983 (FY 83) OMCs were responsible for \$513,158 in counterfeit U.S. currency. In FY 84 this figure jumped to \$600,892, representing a 17% increase. Color copiers were responsible for only 1% of the OMC counterfeits in FY 83. This figure increased to 49% in FY 84 and to 50% in the first half of FY 85. Increases are caused by enhanced image quality and availability.

It appears that the new major threat in counterfeiting will be the monochromatic copier. This is essentially a black and white copier that uses an interchangeable toner reservoir. Therefore, copies can be produced with a variety of colors by running the copy through the machine several times and changing toner cartridges. Canon introduced this concept in 1983 with their personal copiers, PC-10/20. Recently Canon, Sharp, Toshiba and Xerox introduced copiers that offer this capability. Toners are available in red, blue, brown and green. Our research indicates that it is certain the rest of the industry will follow this trend in the near future.

When examining counterfeits produced on an office machine copier, two questions come to mind. Can we determine the make and model of copier that was used to produce a counterfeit, and if we have a suspect machine, can we say that a particular machine was used to produce the counterfeits to the exclusion of all others?

The first question is the most difficult to answer. In order to perform an identification of an office machine copier, we must first assume that there are detectable differences between copiers. Copiers can be categorized into groups such as types of paper, paper feed direction, paper format, toning system, development system and fusion. Based on these classifications alone some groups will be large and others small. The ability to

successfully identify a particular make and model will depend on the size of the group in which the questioned documents fall. We are currently trying to enhance this classification by testing the composition of the photocopier toner. We believe that the toner composition will give added clues toward identification. It is also known that there are many pirate companies manufacturing and selling replacement toner under an infinite number of names. This certainly will make our classification more difficult; however, by classifying and computerizing the results we feel that we can increase our identification ability.

As photocopiers are used, they develop many individual characteristics. For example, when OMCs first come from the factory they are essentially in top condition. As they are used and abused they accumulate dirt and scratches on the glass platen, photoreceptor and document transport mechanism. These types of trash marks are often found on documents and can easily associate a particular copier to a counterfeit.

Paper Analysis

Paper analysis plays a very important role in examination of counterfeit documents. Counterfeiting requires that large quantities of preferably high rag content paper be purchased. This is usually a recent purchase and leaves a trail to the counterfeit operation.

As new counterfeits appear they are systematically examined for the presence of a watermark. Paper containing more than 25% cotton will usually contain a watermark. A watermark is more important in a counterfeit investigation than other types of investigations because it leads to the paper purchase and the beginning of the trail.

Watermarks are put into paper by a dandy roll when it is being manufactured. Usually watermarks are located around the dandy roll so that one watermark will be produced on every 8-1/2 x 11 inch sheet of paper. When counterfeit currency is produced, as many as five counterfeit notes can be printed on one sheet of paper. Therefore, if we also consider waste, there is only a 15% to 20% chance of finding a watermark on any single counterfeit note.

Realistically, only a partial watermark is usually found on a counterfeit note. Because this information is so vital in a counterfeit investigation, several years ago the U.S. Secret Service undertook an extensive effort to collect and computerize information on watermarks. This information was collected from the dandy roll manufacturers in the United States and from reference literature such as "Lockwoods Paper Trade Directory" and "Phillips Paper Trade Directory of the World."

Our computerized watermark file now has more than 23,000 entries of private and commercial watermarks that are used throughout the world. Specifically, this system contains information such as the paper manufacturer, country of origin and reference source and acts as a directory for microfilm retrieval. Indirectly,

by researching the microfilm records, a copy of the watermark and dating information is available.

The U.S. Secret Service has a routine policy to perform semiannual paper supply house canvasses. This means that all of our field offices and resident agencies are required to contact the major distributors of paper in their districts and advise them that we are interested in any suspicious individuals who may purchase paper. This type of liaison coupled with watermark information is important to our counterfeit investigations. A 1983 study showed this system directly responsible for the seizure of more than \$12 million of counterfeit U.S. currency.

Paper fiber analysis also has some application to the examination of counterfeits. For example, the fiber composition may be characteristic to one particular area of the world. Coupling this information with paper manufacturers' distribution patterns can suggest the geographic area of origin. In addition, paper fiber analysis is routinely used to compare the paper of counterfeits to paper found in suspected print shops.

Ink Analysis

The technical comparison and identification of writing and printing inks has been a problem plaguing forensic scientists for many years.

Writing inks produced before 1950 were usually washable dyestuff or iron gallotannate type fluid inks. Technical examination of these inks was limited to chemical spot tests for iron, vanadium, chromium, etc., and visible behavior under ultraviolet and infrared light. In the mid 1940s the ball point pen was marketed and began to have widespread use. Dating of these writing inks can be accomplished by many methods, including the determination of gross formulation changes such as the introduction of copper phthalocyanine dyes, date of introduction of a specific formula and the degree of evaporation that has taken place on a written line. The accuracy of these examinations is greatly dependent on the strict quality control present in the production of these writing inks.

Counterfeit security documents are routinely produced using printing inks rather than writing inks. Each of the various printing processes requires different inks to produce the final image. Inks generally consist of pigments and dyes, resin vehicles in which the pigment is dispersed, solvents to control consistency, and drying and special property additives. The adherence to specific formulations is not as strict with printing inks as it is with writing inks. Writing inks must be amenable to smooth flow over a ball or through a nib. Once a usable formula is achieved, most writing ink production companies will maintain a formula for a period of time, making formula determination and date bracketing possible. Many printing ink formulations change quite often even within the brand and formula number. This makes formula identification and date determination extremely difficult. However, the forensic examiner may use comparison techniques when

viewing counterfeit documents produced using printing ink. Comparison techniques include use of a visible microspectrophotometer, thin layer chromatography and high-pressure liquid chromatography.

The visible microspectrophotometer allows the forensic examiner to obtain the visible light spectrum pattern for a colored substance. The examiner focuses by using a microscope with approximately 20x magnification. The instrument detects absorption of light by use of a 10 nm band filter and a photomultiplier tube between 400 and 700 nm giving the visible light spectrum for that ink. The spectrum pattern can then be compared to that produced by other samples to determine similarity or difference.

Thin layer chromatography (TLC) is a technique useful in comparing dyes, some pigments and some ultraviolet fluorescing components. Ink samples are removed from the document using a blunted hypodermic needle or a scalpel. These samples are immersed in pyridine or chloroform/methanol depending on solubility characteristics. Once extraction has taken place, the examiner transfers the extracted ink to a TLC plate. The TLC plates currently used are glass-backed silica gel plates. For best results, questioned and known samples are run simultaneously with appropriate paper blanks. The plate is dried to remove moisture and the extracting solvent vehicle. The plate is next immersed in a tank containing a solvent system consisting of ethyl acetate: ethanol: deionized water (70:35:30). If necessary, further component separation can be achieved using a solvent system of a different polarity. The technique is very sensitive and provides excellent differentiation among certain ink formulas. The relative ratio of the various components can be determined using a densitometer.

High performance/pressure liquid chromatography is useful in comparing resinous components or fatty acids present in inks. Separation of components occurs in a packed column rather than on a glass plate. The sample is pushed through the column under high pressure using a liquid mobile phase. Separation occurs as a result of solubility interaction between the sample and the column packing material.

Research continues regarding comparison techniques applicable to the identification of printing inks.

Counterfeit Credit Card Production

Credit cards are produced using similar equipment and techniques as for counterfeit currency. The two main printing processes are offset lithography and silk screen—the same processes used by legitimate credit card manufacturers.

The production of credit cards differs from currency only in that plastic rather than paper is used to receive the final image. Plates for the front and back of the cards are used for placing ink onto the plastic surface. Quality control, special inks and techniques used by authorized card manufacturers result in a higher quality product than the counterfeiters can pro-

duce. Genuine card standards have been established by the American National Standards Institute and individual credit card companies.

The Secret Service has identified major suppliers of the basic elements used in the production of cards, such as plastic, inks, magnetic stripes, signature stripes, holograms and embossers. With information currently in our files as a result of the cooperation between these manufacturing companies and the Secret Service, we will be able to direct our agents to local suppliers of plastics and inks that were used to produce counterfeit cards.

In addition to the basic materials, the card companies furnished sample cards, specifications and other technical assistance.

Within the Secret Service and with additional research efforts solicited from the academic community, the basic materials for card production are being analyzed for their identifiable characteristics. This same type of joint effort is used by the Secret Service in the suppression of counterfeit currency.

In addition to the basic materials of the card and its production, we have established reference files of embosser standards and are now able to determine the make of embosser used on counterfeit cards. Research is underway to establish techniques to identify a particular embosser as having produced embossing on a single card.

Association of Counterfeit Cards

When counterfeiters produce currency or credit cards, identifiable defects are usually found in the products they produce. These characteristic defects are reproduced with each production run. The Secret Service is developing a specimen file and circularization system for credit cards similar to the one for currency. During the initial development phase of this file, several

associations were made between cards manufactured in the same plant but used in different parts of the country.

Magnetic stripes are used on legitimate credit cards to record the account number and other information that identifies the card and account holder. Many times information obtained from the mag stripes can help lead to the source of an altered card.

The alteration of a credit card occurs when the embossed material on the card is changed. Most of the time all of the embossed material on a card is removed by techniques that attempt to return the card to a flat sheet of plastic for re-embossing. In most cases, evidence of the alteration attempt is obvious. Laboratory analysis of alteration techniques is conducive to altered credit card associations.

Other Documents

Many Secret Service cases involve the fraudulent use of stolen cards, applications for legitimate cards that are then used in a fraudulent manner, the collusive merchant who establishes a "store-front" business only to defraud the card companies or the con-men who obtain legitimate numbers and make purchases that run up the balance of the card holder.

In each of these operations, paper items are generated that contain handwritten and hand-printed material. Through conventional handwriting and fingerprint development techniques, individuals can be associated to the fraud.

Every step in the issuance of a legitimate card, the production of a counterfeit card and the use of either results in the generation of physical evidence. This physical evidence is evaluated by forensic scientists of the Secret Service for identification of its source or the people who have come into contact with those items.

METHODS FOR EXAMINING QUESTIONED DOCUMENTS USING THE SCANNING ELECTRON MICROSCOPE WITH EMPHASIS ON SEQUENCE OF WRITING PROBLEMS

Peter J. Nolan

Metropolitan Police Forensic Science Laboratory
London, England

The use of the scanning electron microscope (SEM) is now well established in many forensic science laboratories throughout the world (Keeley and Robeson 1975; Pfister 1982). Reports of the potential of the SEM were first published more than 15 years ago (Bradford and Devaney 1970; Williams 1971). Successful applications were initially confined to X-ray microanalysis in the SEM (SEM/XRS). The ability of the SEM to examine and compare very small contact trace materials, such as chips of paint or fragments of metal, was quickly exploited. In contrast, however, early applications of the SEM purely as a microscope, rather than as an analytical instrument, were not as successful. Initial reports of experiments in determining sequence of writing of crossing ball point pen lines were not encouraging (Bradford and Devaney 1970; Oron and Tamir 1974; Williams 1971). More recently there has been a steady improvement in SEM design and capability. Improvements to signal detectors and stage design have been particularly beneficial and the examination of uncoated items, such as paper, with a low-energy electron beam (less than 1000V) has shown some promising results (Baier 1983).

The extent of applications of the SEM in forensic science is wide, ranging from paint, glass and metal analysis to the identification of particles of gunshot residues on the hands and clothes of suspects involved in shootings. Microscopy of fingerprints and the determination of sequence of writing are also examples of the use of the SEM. An important prerequisite feature of all these applications is that they provide information that is unattainable by other methods available in the laboratory. Despite the high initial cost of an SEM facility, it has been shown that over the lifetime of the equipment the cost per case is no higher than any other laboratory examination. Over a 10-year period the cost of the equipment is insignificant in comparison with staff salaries (Keeley 1976).

INSTRUMENTATION

The SEM is an instrument designed to be able to examine the surface of solid samples over a wide range of magnification ($\sim 40\times$ to $100,000\times$). The physical interaction of a finely focused, high-energy electron beam with the surface of a sample is a complex process that produces a variety of different signals such as X-rays and secondary electrons (Figure 1). Various detectors situated within the SEM chamber permit the material

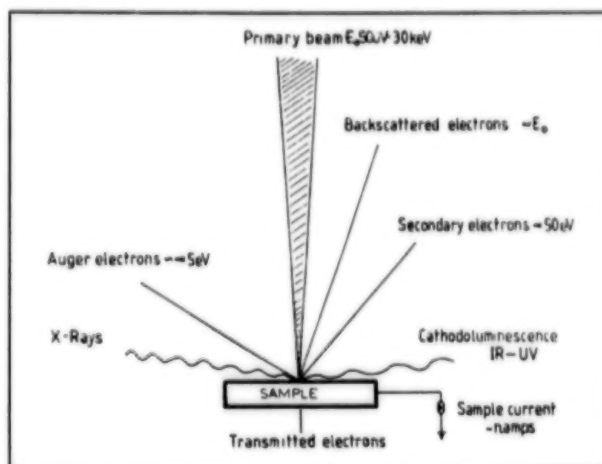


Figure 1. Diagram showing electron beam-specimen interactions.

being examined to be characterized in a number of ways.

The optimum instrumental conditions for examining questioned document samples are varied and depend strongly on the sample and to some extent on the SEM being used. For sequence of writing determinations, instrument conditions can sometimes be critical. The SEM micrographs of indentations in paper caused by writing instruments such as ball point pens and typewriters, can be critically affected by the sample to electron detector geometry. Figure 2 shows a series of micrographs of the same two crossing ball point pen lines. The micrographs, which have been taken in the SEM using a scintillator-type backscattered electron detector, are strongly dependent on the position of the sample relative to the backscattered electron detector. The appearance of the crossover can be completely altered by rotating the sample through 90° , 180° and 270° (Figures 2b-d). Derivative processing of the image should also be used with caution; the image produced will show rate of change of contrast, causing features that are parallel to the direction of the scan of the electron beam to be attenuated (Figure 3). Generally with crossing ball point pen lines, the SEM can be adjusted in a variety of ways to demonstrate either sequence. However, further investigations are anticipated involving the use of an annular, semiconductor-type backscattered detector together with the measurement of height differences taken from stereo pairs.

Novel methods for examining questioned documents using the SEM have been reported by many forensic

science laboratories (Baier 1983; Koons 1985; Mathyer and Pfister 1984; Nolan *et al.* 1982; Waeschle 1979; Warman *et al.* 1984). Table 1 outlines and categorizes the types of questioned documents examined in the author's laboratory, according to the extent of sample preparation required. Applications involving X-ray microanalysis generally require 1 mm disc samples; these can be taken with a modified hypodermic needle (Nolan *et al.* 1982). SEM microscopy of questioned

documents normally requires examination of larger areas. For samples where sequence of writing is to be determined, the complete intersecting region needs to be cut out and attached to a specimen stub and coated with a thin layer of carbon or gold. SEM magnifications of less than 4x are necessary for the microscopy of fingerprint deposits that have been developed using a technique called physical developer (PD). This unusually low SEM magnification corresponds to a

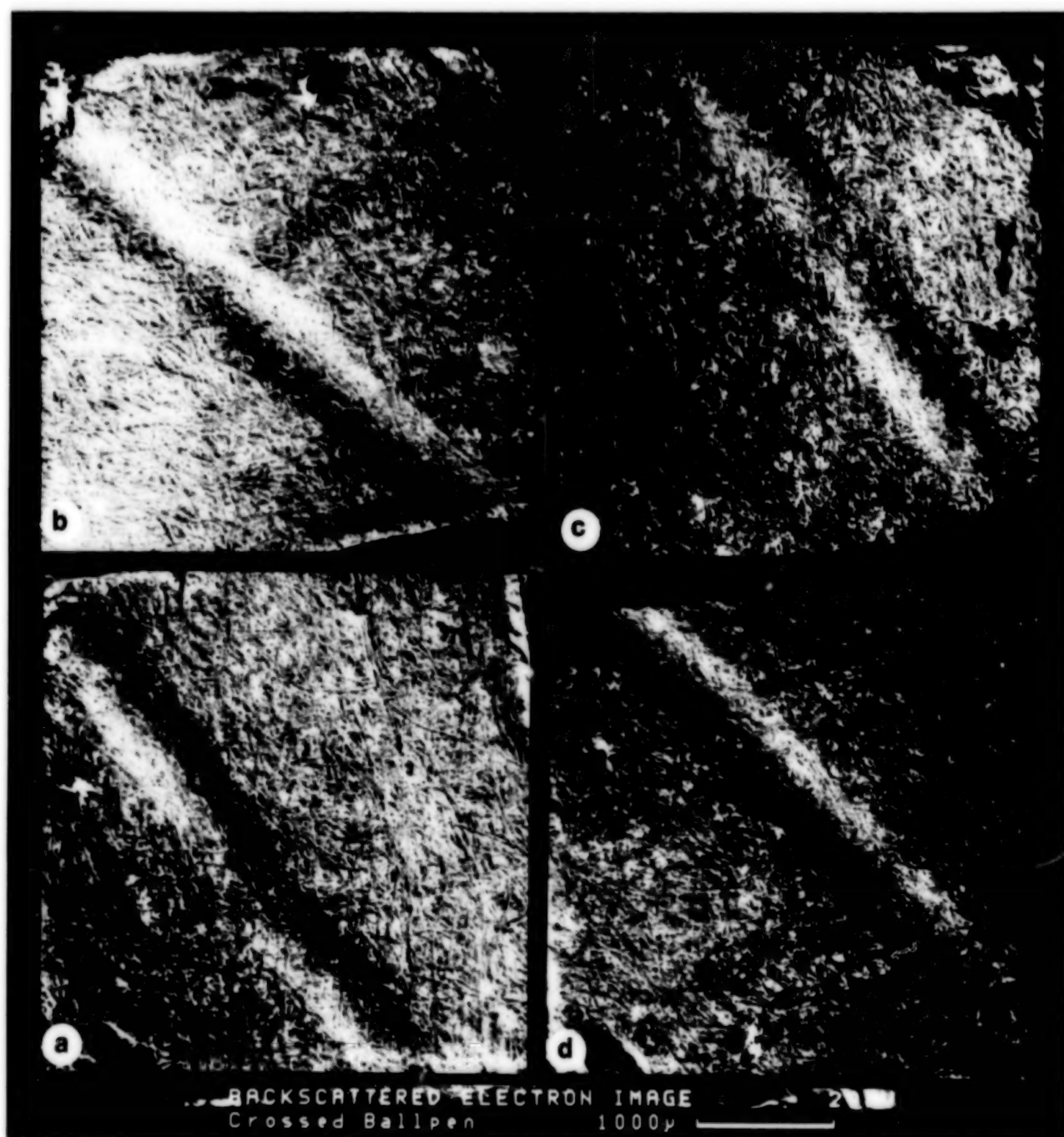


Figure 2 a-d. A series of backscattered electron images of the same intersection of crossing ballpoint pen lines. In each micrograph the sample has been rotated by 90° with respect to the backscattered electron detector: demonstrates critical effect of sample geometry. The line written last—i.e., uppermost, is visible only in (b) and (d); the line written first is visible only in (a) and (c).

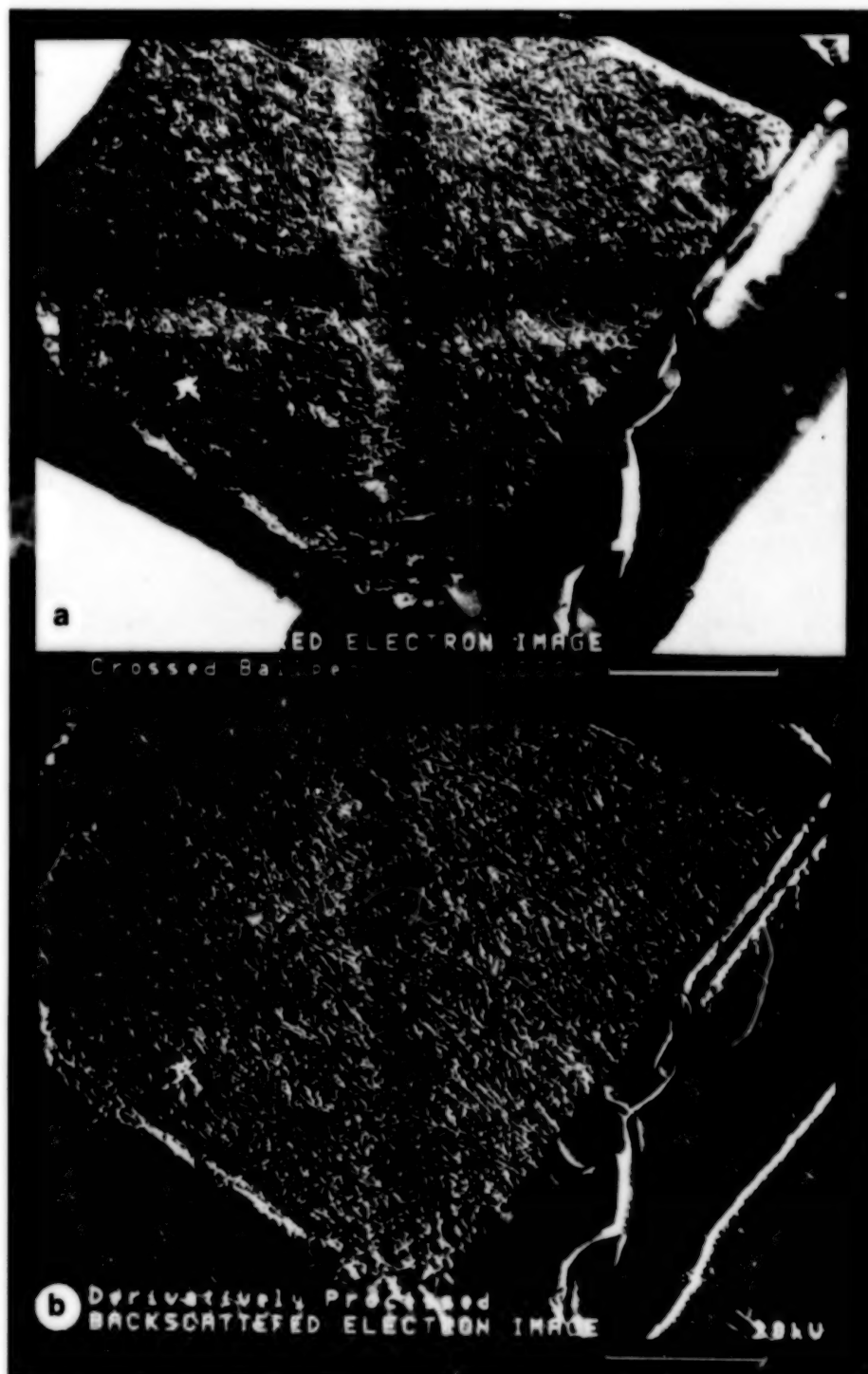


Figure 3. (a) Backscattered electron SEM image of crossing ballpoint pen lines.
(b) Derivatively processed image of figure 3(a) showing attenuation of detail.

Table 1. DIFFERENT TYPES OF SAMPLE ENCOUNTERED IN CASEWORK CATEGORIZED ACCORDING TO METHOD OF SAMPLING

A	B	C
(i) Paper loading	(i) Establishing sequence	(i) Tachograph charts
(ii) Printing and writing inks	(ii) 'Magnetic' inks on cheques	(ii) Valuable documents (e.g., stamps)
(iii) Erasable ballpen inks	(iii) *Labelled security inks	
(iv) Ink remover	(iv) *Magnetic coding on credit cards	
	(v) Dry transfer instant lettering	
	(vi) Photocopy toners	

*Not encountered in casework.

Note: Category A: 1 mm disc samples.

Category B: Sample required larger than Category A.

Category C: Complete item examined (uncoated).

sample area of at least 25 mm x 25 mm. Figure 4 demonstrates the benefit of using the SEM for a sample of newsprint where the fingerprint ridge details are partially obscured by heavy, detailed printing. By careful choice and adjustment of the SEM operating conditions, the background details can be successfully eliminated.

Document examiners are instinctively reluctant to permit any sampling of questioned documents, although the courts tend to have a more realistic attitude in this respect. The examination of valuable documents such as stamps presents a problem in that no sample preparation is acceptable. For samples of this type, the only alternative is to accommodate the complete item in the SEM chamber and use conditions that minimize problems such as charging. An SEM with a large specimen chamber is essential if large items such as passports or sheets of newsprint are to be successfully accommodated and examined. Supplementary pumping of the chamber may be necessary where large items outgas excessively, preventing the SEM from reaching its preset vacuum.

Figure 5 shows a series of three 20-ore Norwegian stamps. It is of great interest to philatelists to be able to visualize important, significant detail on stamps that has been obscured by franking ink. The value of the stamps shown is significantly affected by the presence or absence of a full stop after the word *postfrim*; two of the stamps have been cancelled in such a way that this region is obscured. Figure 5 (b and c) demonstrates that the SEM was capable of imaging detail present beneath the franking ink and show that one of the stamps contained a printed full stop. The stamps were shrouded in aluminum foil with a small hole cut out

to expose the area of interest. The effects of charging were sufficiently reduced to permit the backscattered electron image to remain stable; the secondary electron image was of no use. The contrast in backscattered electron images is directly related to the average atomic number of the sample under examination. The printing ink of the stamps contains lead and chromium, probably as the pigment lead chromate (Figure 6). The franking ink contains material of low average atomic number, probably carbon black. The relative difference in atomic number between the inks permitted the SEM to be adjusted to penetrate through the franking ink and image the printing ink beneath.

Although this technique of shrouding the sample in foil can work well, it is limited by the relatively low magnification that is attainable before charging becomes a serious problem. It has been shown that low electron beam voltages of less than 1kV can be beneficial in this respect, however applications are similarly limited to relatively low magnifications because of the low resolution attainable (Baier 1983).

Neutralization of Charging Effects of Uncoated Samples

A possible solution to counteract the effects of charging of uncoated samples could be to direct a source of positive ions at the sample to neutralize the surplus electrons that cause charging. Preliminary results from a device designed to do this indicate that it may be of considerable benefit in the examination of questioned documents. The micrographs shown in Figure 7 demonstrate the effect of using this device.

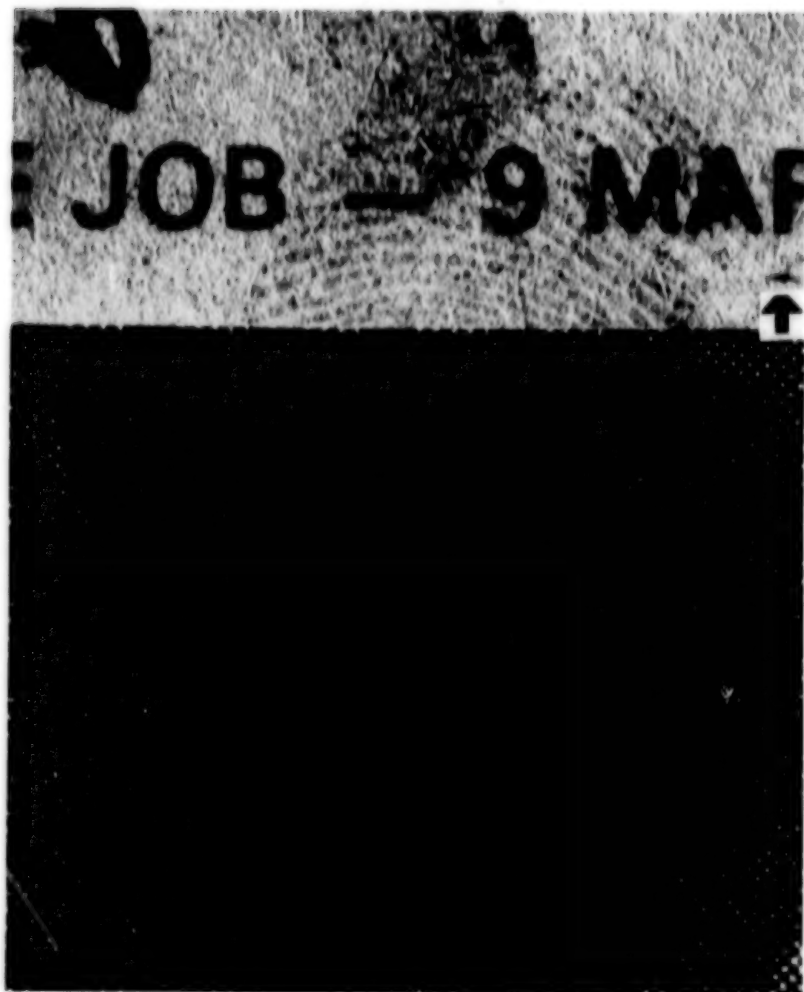
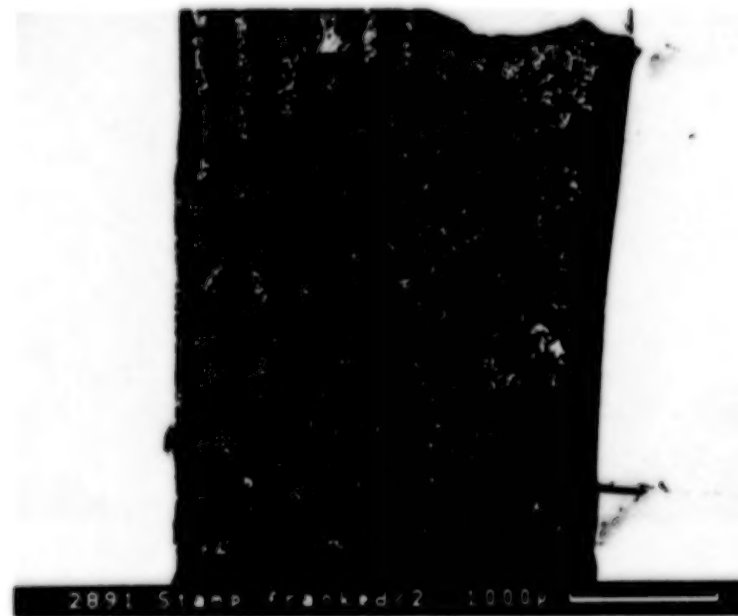
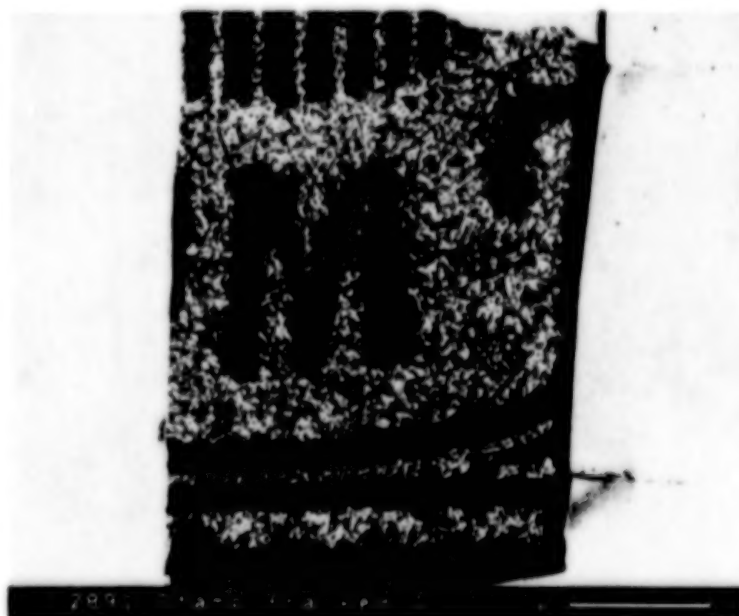


Figure 4. (a) Fingerprint on newsprint developed using Physical developer (PD). Important ridge detail is obscured by heavy, detailed printing.



(b) Reverse contrast backscattered electron SEM image (15 kV) of fingerprint on newspaper. Area examined is the same as in 5(a). Obscuring detail from printing is completely removed. Arrows indicate a fiducial feature present in both (a) and (b).

Figure 5. (a) 3 20 ore Norwegian stamps: Presence of fullstop after the word 'postfrim' is of interest to philatelists; this region is obscured by franking ink in middle and right hand stamps. Backscattered electron SEM image of obscured region is shown in (b) middle stamp (no fullstop) and (c) righthand stamp (full stop visible). Stamps were examined without being damaged in any way.



20 ORE NORWEGIAN STAMP: SEM/MPA X-RAY SPECTRUM

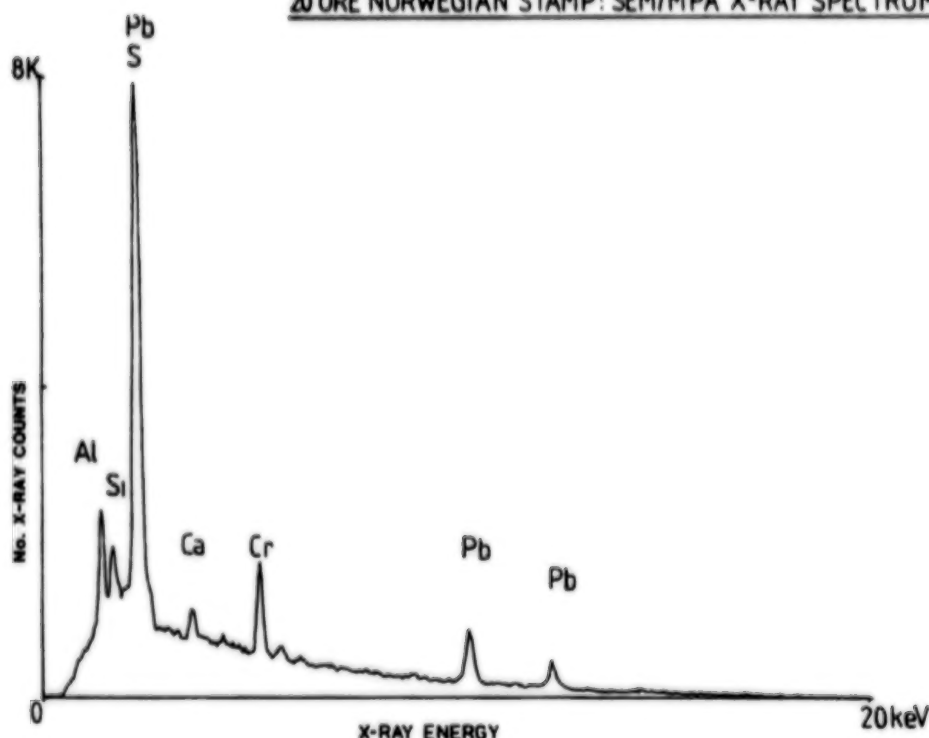


Figure 6. X-ray spectrum of printing ink of 20 ore Norwegian stamp.

The micrographs are from the same area of a questioned football match ticket on which dry transfer instant lettering has been used. Different makes of instant lettering can be classified according to their SEM morphology and elemental composition. Like the stamps, the ticket was covered in foil and examined without causing any damage. The effect of the ion source in eliminating severe charging over a field width of 2 mm is shown in Figure 7(a); Figure 7(b) shows the same area examined with the ion source switched off. If the use of this device as a charge neutralizer is as successful in a wider range of samples, it will then be possible to offer questioned document examiners a complete SEM analytical service that causes no damage to their samples. Successful examinations will be limited by the ability to accommodate the sample in the SEM chamber.

Sequence of Writing Determinations: Strategy

The problem of determining sequence of writing of crossed or intersecting writings generally has received considerable attention from many document examiners over the past 40 years (Mathyer 1980, 1981). It is well established that there is no single method that can determine the sequence in all combinations of writing media. Even when considering a specific combination of writing, a successful method that can determine the sequence on all occasions is very rare. For most methods reported there will always be some samples where, for a variety of reasons, no assignment of se-

quence can be made; the success of these methods relies on a 100% guarantee of no incorrect assignments.

Various novel methods for determining sequence of writing using the SEM have been reported (Baier 1983; Koons 1985; Mathyer and Pfister 1984; Nolan *et al.* 1982; Waeschle 1979). Table 2 has been compiled from a review of the literature and shows at a glance those combinations of writing media that have been investigated using the SEM. Broadly speaking, the SEM is successful when: (a) the two writing media are different, that is, heterogeneous crossings (Mathyer 1980, 1981), and/or (b) at least one of the writing media leaves an identifiable deposit on the surface of the fibers of the paper.

When confronted with a sequencing problem, it is often necessary either to evaluate a proposed new method, or to check that an existing method is applicable to the questioned writing. For example, there are two types of textile typewriter ribbon. One of these is loaded with an inorganic pigment or extender. Deposits of this material on the paper surface are easily visible in the SEM and can be usefully employed to determine sequence. The other type, however, contains only an organic dye with no inorganic extenders. Deposits on paper from this type of ribbon are generally not sufficiently visible in the secondary or backscattered electron images of the SEM, although some success has been reported using the cathodoluminescence image (CL) (Nolan *et al.* 1984).

Critical evaluation of new methods, if possible in comparison with existing methods, is normally

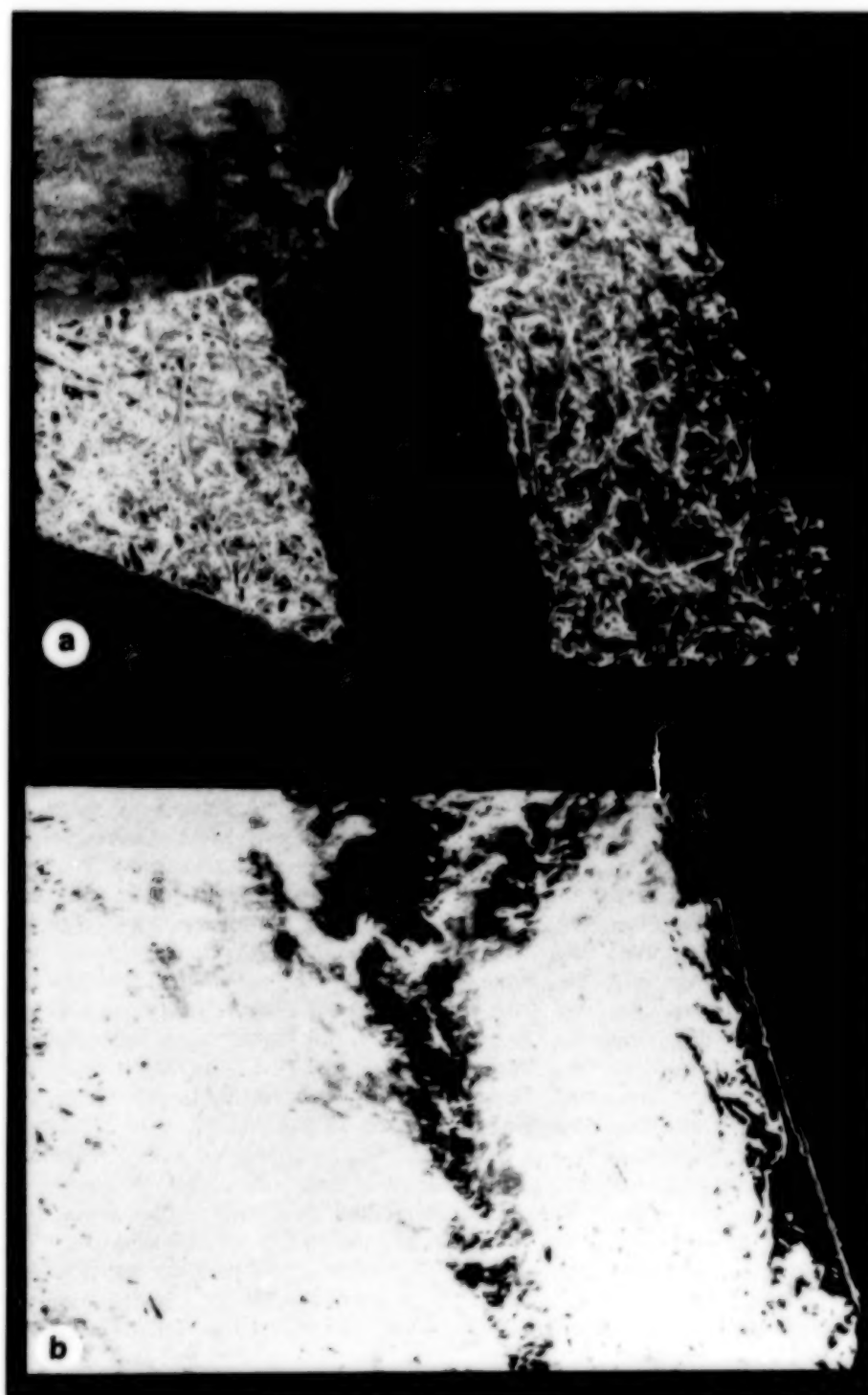


Figure 7. Secondary electron SEM images of dry transfer instant lettering on suspect football match ticket. The difference between the two micrographs (of the same area of the ticket) is due to the use of an ion beam source as a charge neutraliser in figure 5(a). The ticket was examined without sampling or causing any damage.

Table 2. SUMMARY OF PREVIOUSLY REPORTED METHODS USING THE SEM TO DETERMINE SEQUENCE-OF-WRITING

	FOUNTAIN FELT PEN	CORRECT- PEN	BALL ABLE TW	TEXTILE PEN	TEXTILE TW 'A'	TEXTILE TW 'B'	PENCIL	CARBON PAPER	STAMP PAD	WAX CRAYON	PHOTOCOPY TONER
Felt Pen E	-	-	N(4)	-	N(4)	Y(5)	-	-	-	-	-
Fountain Pen	-	-	Y(4)	Y(4)	Y*(4)	-	-	-	(5)Y	-	-
Correctable TW	N(4)	Y(4)	-	(1,2,3, 4,5)Y	-	-	-	-	(4)N	-	-
Ball Pen	-	Y(4)	(1,2,3, 4,5)Y	(1,2,3, 4,5)N	Y(1,4)	(5)N	(1,4)Y	(1)Y	-	-	(4)Y
Textile TW A	N(4)	Y(4)	-	(1,4)Y	-	-	(4)Y	-	(4)N	-	-
Textile TW B	Y(5)	-	-	(5)N	-	-	(5)N	-	-	-	-
Pencil	-	-	(2,4)Y	(1,4)Y	(4)Y*	-	(1)Y	-	-	-	-
Carbon Paper	-	-	-	(1)Y	-	-	-	-	-	-	-
Stamp Pad	-	-	(4)N	-	(4)N	-	-	-	-	-	-
Wax Crayon	-	(5)Y	-	-	-	-	-	-	-	-	-
Photocopy Toner	-	-	-	(4)Y	-	-	-	-	-	-	-

Key: 1. Waeschle

2. Baier

3. Mathyer & Pfister

4. Koons

5. Nolan *et al.*

* Depends on type of paper

N SEM Method not successful

Y SEM Method successful

TW 'A' Refers to textile typewriter ribbon containing an inorganic extender

TW 'B' Refers to textile typewriter ribbon that contains no extender

Note: Writing media listed in left column are for those written first; corresponding writing medium in top row written last—i.e., uppermost.

necessary in order to establish whether the new method offers any real advantages. Experiments involving parallel trials can be usefully conducted for this purpose (Nolan *et al.* 1982). The following list of guidelines outlines the strategy that has been adopted in the author's laboratory:

1. Examination of known examples by a range of available techniques.
2. Observation of possible criteria.
3. Possible method proposed.
4. Proposed or reported method comprehensively and critically tested by trial of undisclosed examples.
5. Parallel trial(s) conducted to establish relative merits between other methods if available.
6. Demonstration of method to include where possible:
 - (a) Results of trials
 - (b) Representative examples also showing any advantages or limitations.
7. During the evaluation stage, when the unknown trial samples are examined, assignment of sequence can fall into one of three categories:
 - (a) Where the criterion for confident assignment is judged to be clearly visible
 - (b) Where there are indications visibly suggesting a particular sequence
 - (c) Where no assignment is possible, that is, no features visible enabling sequence to be established.
8. When examining an intersection on a questioned document, a noncontentious area of each writing

should be examined first to check that the morphology is similar to that expected and tested during steps 1 through 5.

Methods that have followed this strategy have already been reported and will not be repeated here (Nolan *et al.* 1982). However, some relevant points from one method can be used to demonstrate the advantages of adopting this critical approach to sequence of writing determinations.

Ball Point Pen Writing and Correctable Carbon Film Typescript

Of all the methods that use the SEM to determine sequence, correctable carbon film typescript and ball point pen writing are most frequently cited in the literature (Baier 1983; Koons 1985; Mathyer 1980, 1981; Mathyer and Pfister 1984; Nolan *et al.* 1982; Waeschle 1979). Most of the examples shown use heavy deposits of ball point pen ink applied over or under the typescript. The results of a parallel trial indicated, however, that ball point pen ink applied with heavy pressure could be successfully identified visually using optical microscopy. The difficulty arose when examining ball point pen deposits applied with light pressure; only the SEM was capable of examining these samples although the characteristic features were not as obvious as other authors have described. Figure 8 shows an example where a heavy deposit of ball point pen ink has been applied over the typescript. The characteristic features are easily visible and the se-

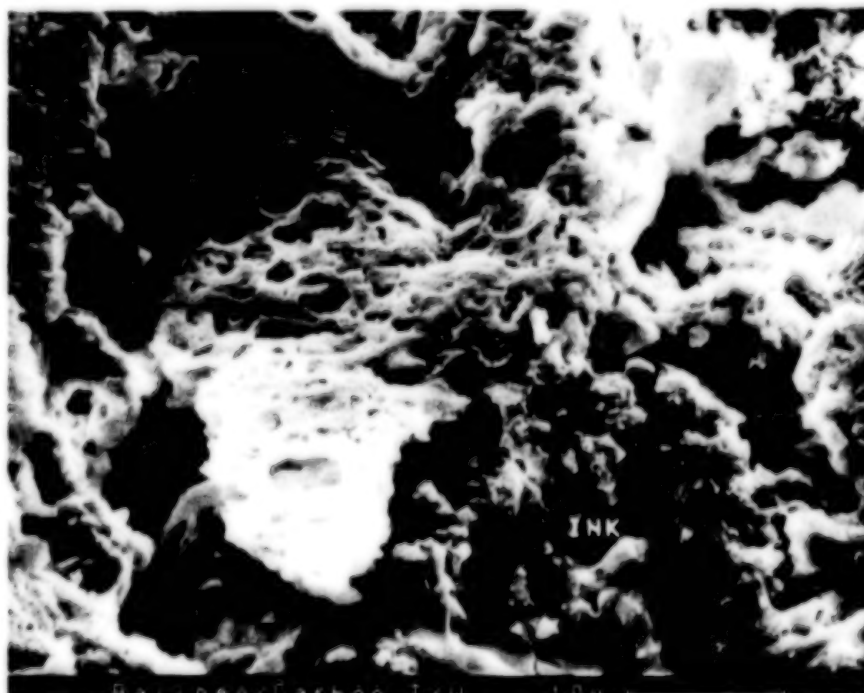


Figure 8. SEM micrographs showing correctable carbon film typewriting over lightly applied ballpoint pen ink on paper.

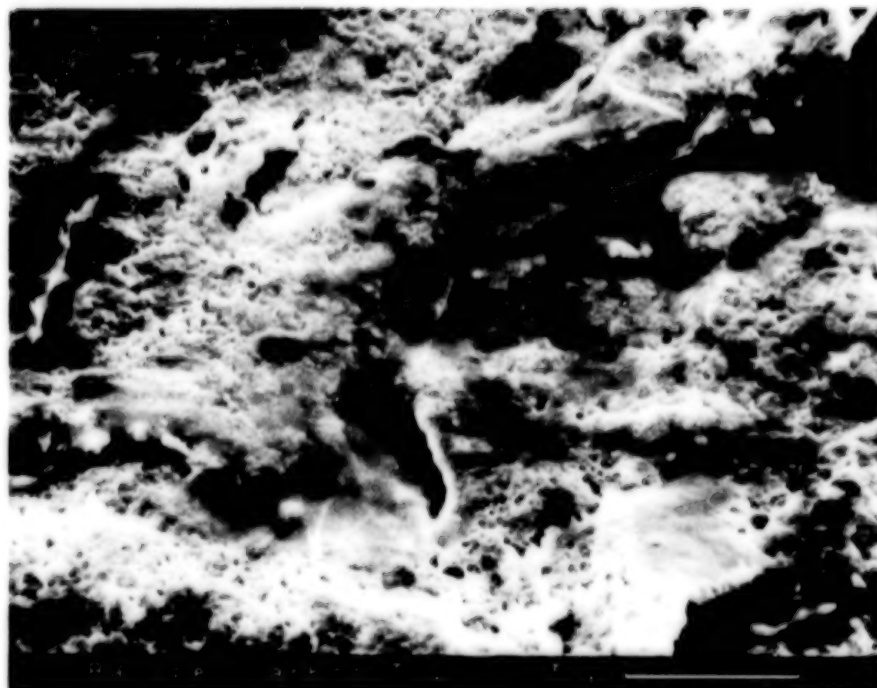


Figure 9. SEM micrograph showing heavily applied ballpoint pen ink over carbon film typescript.

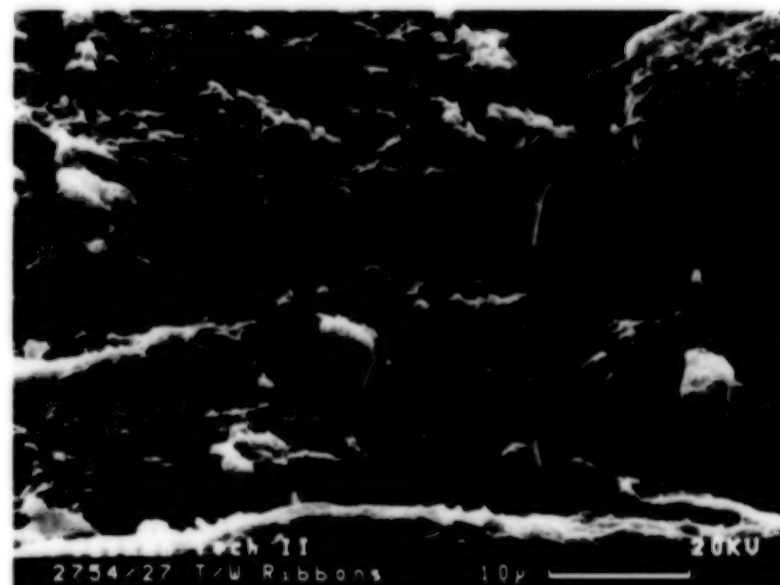
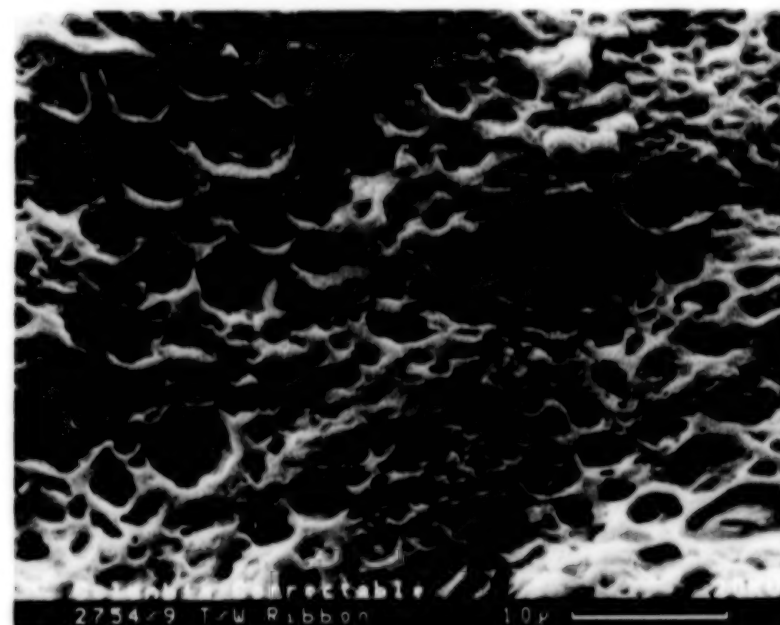


Figure 10. SEM micrographs showing difference between (a) correctable carbon film typescript and (b) "tech" carbon film typescript.

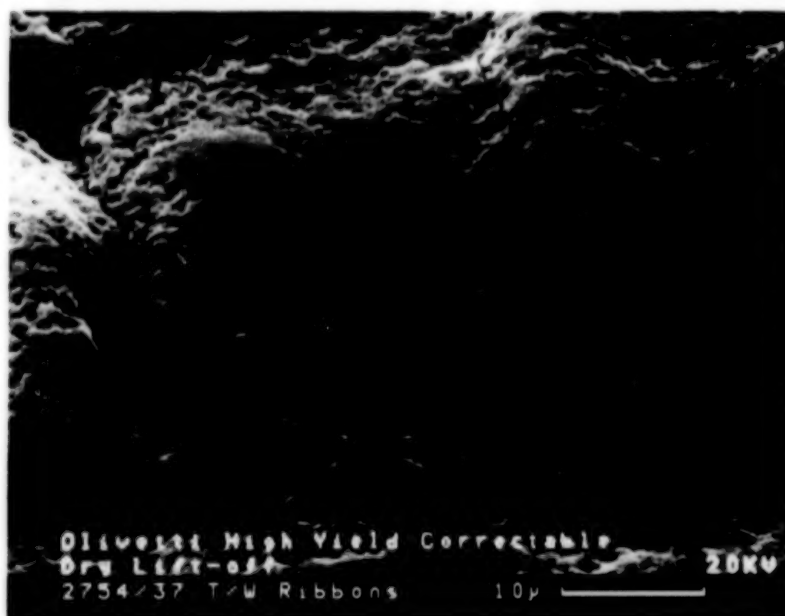


Figure 11. SEM micrograph of different make of correctable carbon film typewriter —see figure 11(a).

quence is immediately apparent. Figure 9, on the other hand, shows an example where the typing has been applied over a light ball point pen deposit. It took an experienced SEM operator 15 to 20 minutes to locate and identify the characteristic features visible in this example.

As part of the evaluation of this method, a survey of carbon film typewriter ribbons was also undertaken (Nolan *et al.* 1982). Forty-four brands of ribbon from 13 manufacturers were examined. Of the 44 samples, 24 were correctable and the remainder "tech" types. It was shown that the morphology of the tech type is completely different from that of the correctable type (Figure 10). Also, although all the correctable carbon typewriting samples had a similar surface morphology in the SEM there were minor but significant differences between ribbons made by different manufacturers (Figure 11). A comprehensive survey of correctable carbon ribbons available in Europe has also been reported and came to the same broad conclusions (Mathyer and Pfister 1984; Pfister 1985).

CONCLUSION

The SEM has been shown to be a versatile instrument capable of providing document examiners with information from a wide range of samples. Whether as an analytical instrument or as a microscope, methods have been developed that can provide information and a quality of evidence that is unattainable by other existing methods.

Substantial progress has been achieved in sample

preparation techniques. Methods have been developed and are envisaged that may permit examination of items without the need for sampling or causing any damage to the item. Novel methods developed using the SEM to determine sequence of writing have been critically evaluated using a strategy that can highlight any advantages and disadvantages. The SEM is not a panacea for sequence of writing or document examination problems in general. Rather, this paper has attempted to place the use of the SEM in its proper context along with the other techniques available in the laboratory.

REFERENCES

- Baier, P. E. (1983). Technical improvements of scanning electron microscopy methods in document examination, *Forensic Sci. Int.* 22:265-270.
- Bradford, L. W. and Devaney, J. (1970). Scanning electron microscopy applications in criminalistics, *J. Forensic Sci.* 15:110.

ACKNOWLEDGMENTS

The author would like to acknowledge the help and assistance from Dr. J. Critchell (CEGB Gravesend UK) for use of a charge neutralizer and Dr. R. L. Williams (Director MPFSL) for supply of the Norwegian stamps. Thanks are also due to Dr. R. H. Keeley and Dr. C. Davies for advice in the preparation of this paper.

- Keeley, R. H. (1976).* The economics of SEM in forensic science, *International J. Legal Medicine* No. 131.
- Keeley, R. H. and Robeson, M. C. (1975).* The routine use of SEM and electron probe microanalysis in forensic science, *Scanning Electron Microscopy*, pp. 479-486.
- Koons, R. D. (1985).* Sequencing of intersecting lines by combined lifting process and scanning electron microscopy, *Forensic Sci. Int.* 27:261-276.
- Mathyer, J. (1980, 1981).* The problems of establishing the sequence of superimposed lines, *International Criminal Police Review*, Part I pp. 238-250; Part II pp. 271-281.
- Mathyer, J. and Pfister, R. (1982).* The examination of typewriter correctable carbon film ribbons (a preliminary study), *American Society of Questioned Document Examiners meeting*, Boston, Mass.
- Mathyer, J. and Pfister, R. (1984).* The determination of sequence of crossing strokes by the "kromekote" paper lifting process and by scanning electron microscopy, *Forensic Sci. Int.* 24:113-124.
- Nolan, P. J., Davies, C. and Filby, A. G. (1984).* Determination of sequence of writing: A strategy for evaluating new methods, *J. Forensic Sci. Soc.* 24:355-356.
- Nolan, P. J., England, M. and Davies, C. (1982).* The examination of documents by SEM and X-ray spectrometry, *Scanning Electron Microscopy* II:599-610.
- Oron, M. and Tamir, V. (1974).* Development of SEM methods for solving forensic problems encountered in handwritten and printed documents, *Scanning Electron Microscopy* I:207-214.
- Pfister, R. (1982).* The use of SEM and associated techniques in forensic science (bibliography), *Scanning Electron Microscopy* III:1037-1042.
- Pfister, R. (1985).* L'emploi du microscope électronique à balayage (MEB) en criminalistique avec prise en considération particulière des possibilités dans l'examen des documents, Ph.D. thesis, Institute of Police Science and Criminology, University of Lausanne, Switzerland.
- Waesche, P. A. (1979).* Examination of line crossings by scanning electron microscopy. *J. Forensic Sci.* 24:569-578.
- Warman, G. P., Curry, C. J. and Burke, P. (1984).* Evaluation of scanning electron microscopy with energy dispersive spectrometry for examining plain paper photocopies, *J. Forensic Sci. Soc.* 24:415.
- Williams, R. L. (1971).* An evaluation of the SEM with X-ray microanalyser accessory for forensic work, *IITRI*, pp. 537-544.

BLANK PAGE

COMPUTERIZED REPORTING

Manfred Hecker

Bundeskriminalamt
Kriminaltechnisches Institut
Wiesbaden, Federal Republic of Germany

At a very early stage, handwriting experts, as the largest group within the Bundeskriminalamt (BKA) forensic science division, started to study the question as to what extent it is useful to apply text processing to the preparation of expert opinions. Such considerations were made primarily in view of the fact that the BKA as a central authority has responsibility for the examination of all handwriting evidence that comes to light in a criminal context in the 11 Federal States for possible interregional links between offenses. In addition, handwriting examinations have to be performed for the investigative divisions of the BKA dealing with crime areas where by law, the investigative responsibility rests with BKA.

This means that about 80,000 to 100,000 documents containing relevant handwriting need to be examined annually. For this task, I have a staff of seven experts who are university graduates, 51 assistants whom we have trained ourselves and four clerical staff.

Consequently, there are many reports to be prepared after the examinations, which in our experience are highly repetitive as far as structure and contents are concerned.

The former practice of simply communicating the result to the submitting authority in a single sentence or just ticking off the appropriate phrase in a form offering various choices was unsatisfactory in several ways. First, the results did not make it clear for the submitting authority, for example, why only a limited degree of probability was chosen with regard to the question of authorship. Thus, the results did not contain a statement to the effect that the restriction was due to the nonavailability of optimal standards or that even with optimal known material no further statement would have been possible because of the small amount or poor quality of the questioned material submitted. As a rule, such summary opinions, or "quickies" as we affectionately called them, led to subsequent telephone inquiries about whether more and what kind of comparison material could possibly improve the results.

The absence of a detailed description of the material submitted also led to some difficulties when the expert later presented his opinion in court and was asked questions about the writing instrument and the paper, which he was unable to answer on the basis of his photostats of the documents. Another drawback of this type of opinion was the lack of transparency for the parties at the trial. The lack of a description of the methods used, the lack of understanding of how the expert arrived at his conclusions, and the lack of a full account of individual findings frequently led to hours of cross-

examination of the expert on general methods of handwriting comparison.

And finally, let me be quite frank about this, the brief statement of findings also created a risk for the examiner of adopting a somewhat more generous approach to the compilation of individual finding than with the elaborate account of each procedural step of the examination. In other words: What goes into my opinion must have been examined, too.

In the situation of contradictory requirements for opinions, that is, on the one hand the desirable immediate communication of the result and on the other hand the large time investment needed for phrasing it, the use of text processing virtually imposed itself.

Of course, one must not forget that we first had to overcome considerable resistance among our own staff, which probably sprang from the fear that the personal note would be missing in the formulation of the opinion or even that stylistic creativity would be abolished altogether. Only the promise that far-reaching attention would be paid to personal preferences in phrasing the text manual, which was to be developed in a joint effort to arrive at an optimal result, started to remove the initial reservations. Also the knowledge that text components would essentially be used only in routine cases, while in cases of special interest there would still be the possibility of "free" linguistic choice, strengthened our staff's acceptance of the new method.

Today, it is considered to be a great advantage and that there is no need to find new phrases again and again for identical or very similar findings and that the considerable amount of time saved can be invested in extraordinary cases.

Practically, because a preliminary stage of the text manual is now available, there are a number of standardized letters stored in the system into which only the specific data of a particular case have to be inserted. Standardized letters are used, for example, where the submitted document yields insufficient graphic evidence or where the search against the reference collection is negative.

The manual is subdivided into the following chapters, which must always be part of the computer-controlled report:

1. Formulation of the Examination Commissioned
2. Description of the Material to be Examined (Description of evidence)
3. Critical Evaluation of the Material Submitted
4. Physico-Technical Examinations
5. Methodology
6. Handwriting Comparison

7. Conclusions

8. References

Individual chapters consist of many text elements covering the majority of the most frequently used evidence characterizations and technical terms.

Let me take Chapter 2 to exemplify the system. Chapter 2 includes phrases such as:

"The following writings are questioned:..."

The questioned writings are written with

....blue

....black

....red

....green

....

....ink

....ball point pen

....felt tipped pen

....fountain pen

....crayon

....in

....Latin cursive script

....German cursive script

....print

....small letter print

....capital letter print

....

The same structuring is used to describe the reference material.

Chapter 3 (Critical Evaluation of Material Submitted) then discusses interpretability, graphic richness, relative synchrony and the volume of the material under examination. Already, at this point, reasons for any qualifying statements in the findings, as far as they are due to the properties of the evidence to be examined, are given, possibly with literature references. Where any such restrictions are caused by insufficient reference material, the appropriate passages from the guidelines for obtaining reference handwriting samples are quoted.

Chapter 4 of the text manual includes the discussion of the different methods of forgery, and descriptions of all common physico-technical test methods by procedure and objective. Chapter 5, methodological aspects, discusses the fundamentals of handwriting comparison, case-relevant particularities such as the examination of old-aged handwritings and, in particular, probability theory.

The Handwriting Comparison chapter points out agreement and, where appropriate, disagreement between the handwriting complexes under examination, first verbally and then, if required,* with a photographic documentation in the annex.

*A photographic documentation is prepared only in cases where the opinion is expected to be maintained in court.

With reference to the chapters on the evaluation of material in hand and on methodology the opinion finally arrives at an assessment of the findings and summarizes it in a statement of probability. The findings structured in this way, together with a literature list containing the most important publications, lend to the expert's opinion the scientific appearance that this discipline deserves.

Those individual text elements are identified by four-digit selection codes, in which the first digit stands for the main chapter (for example, 1 = Examination Commissioned, 2 = Evaluation of Material, and 7 = Literature) and the second, third and fourth digits stand for combinations of whole passages, individual sentences or parts of sentences. This, for example, is an extract from Chapter 3, Critical Evaluation of Material Submitted:

3000 Reference material

30 The reference material consists of

..1. one

..2. several

handwriting sample(s)

...1 originated naturally in cursive script.

...2 originated naturally in print.

...3 originated naturally in small letter print.

...4 originated naturally in capital letter print.

...5 originated on request in cursive script.

...6 originated on request....

31.. This material had been submitted

.. 1. in the form of an original.

.. 2. in the form of a photostat copy.

.. 3. in the form of a photographic reproduction.

.. 4. in the form of a carbon copy.

... 1 Regarding quality and quantity, it is to be considered as fully suitable for comparison with the questioned material.

... 2 Therefore it is to be considered as suitable for comparison only to a limited degree.

... 3 It is to be considered as suitable for comparison with the questioned material as far as quantity, but not quality, is concerned.

... 4 It is to be considered as suitable for comparison with the questioned materials as far as quality, but not quantity, is concerned.

... 5 It is to be considered only conditionally suitable for comparison, because no naturally originated reference material is available.

The two codes: 3022 and 3113, for example, represent the following statement:

"The reference material consists of several samples originated naturally in block letters and is to be considered as suitable for comparison with the questioned material as far as quantity, but not quality, is concerned."

At first sight, the whole thing will surely look very complex and unclear, and initially this gave rise to a massive prejudice on our staff. I can assure you, however, that especially the frequent combinations sank in very fast. In particular, the chapters Physico-Technical Examinations, Methodological Basis and References to Literature differ only insignificantly from one opinion to another. Our experience so far goes to show that preparing a record of examination by means of selection codes takes only half the time required for an elaborately phrased opinion.

Further concatenation of several text elements to describe those cases that statistically are the most frequent, is expected to yield considerable timesaving in drawing up opinions.

The text processing system we use is the Siemens Text System 580 Model 5823-2. The unit employs floppy disks, of which it needs only two to store the entire text manual for the handwriting application.

It is important to note that the writing time required for such opinions (input of the "Write" instruction + printout) is only one-fifth of the conventional process using a typewriter.

The error rate in inputting four-digit codes is substantially lower than in handwritten drafts or tape-recorded dictation. And finally, the time expenditure for proofreading is considerably lower because, at least within the text elements, no typing errors will occur.

Depending on the type of machine used, the text manual may be equipped with internal logic that will reject erroneous user-made combinations of incompatible text elements.

This text processing system has not been designed primarily to cope with the extraordinary case in the expert's work, although even this can be done with some time saving provided one is familiar enough with the system. Rather, its purpose is to assist in the efficient and high-quality handling of the large number of "average cases" with which we are faced. We also believe that opinions are no less individual for it, because there is no change whatsoever in the intellectual assessment of individual findings and in making a statement of identity or not; the only difference is that there is no daily new verbalizing, which depends on what shape the examiner is in, and which is nothing else but falling back on more or less fixed personal preferences.

We set our hopes, which in part have already been confirmed, on this procedure to achieve more trans-

parency and greater descriptiveness of handwriting opinions and see in the "check-list" nature of the text manual a certain constraint for the examiner to practice self-control with a view to working without fault, methodologically and formally.

We do not think the formal uniformity of our opinions is a disadvantage. On the contrary, we expect it to produce in the user of the opinion not only the impression of the interexpert validity and therefore, reliability of the method of handwriting comparison but also the realization that handwriting comparison is more than a prescientific and amateurish assessment of graphic facts.

Finally, this procedure offers an advantage that is not insignificant from the police point of view, that is, a dramatic increase in the speed and security of communication.

Once the computer-assisted image-processing and pattern-recognition system FISH is put into live operation, interfaces will be created at various points of the new work flow. Today, text components are manually assembled by the expert and forwarded to a remote typing pool; in the future, he or she will be able to complete the whole process directly at his or her work station. Since all case data and handwriting features are stored on the computer, it is expedient to combine that information with the text components required in a given examination and to print out a combined text/image log of the work done.

Even logical linkages can be implemented; for example, whenever defects are noted in the comparison material the relevant passages in the police regulations on how to obtain comparison material and where to find it can be quoted automatically.

Consistency checks are also conceivable; for example, the omission of certain steps of the examination could cause the system to report an error and block future processing; or where a deficiency is noted in the material, only certain degrees of probability are admissible.

Because it has been realized at some point, that the optimal phrasing has been found for certain facts, this technology meets with broad approval among German police experts. Numerous State Criminal Police Offices have also decided to adopt our text manual.

Thus, a step has been made to catch up with crime somewhat faster without having to accept a loss in quality.

BLANK PAGE

ESDA SAFETY

Franklin P. Lundblad

U.S. Postal Inspection Service
Washington, D.C.

Some activities in forensic and crime laboratories, research laboratories and similar facilities pose special problems related to employee safety and health. These activities can result in potential chemical, biological, physical and energy exposures. Chemical exposures vary qualitatively and quantitatively. Biological hazards include infectious agents encountered in samples and evidence and cultured in media. Physical hazards result from broken glass, syringes and projectiles ejected from centrifuges. Hazardous energies are also present in the form of electrical energy, ionizing and nonionizing radiation and lasers.

Because of the wide variety of potential hazards present in the laboratory, the best policy for ensuring a safe and healthful work environment is to have a formal, established safety and health plan that provides for standard operating procedures, use of personnel protective equipment, and training and supervision. Proper facilities and equipment will minimize hazards and exposures through ventilation, other engineering controls and fire protection.

ESDA POTENTIAL EXPOSURES

The Electrostatic Detection Apparatus (ESDA), manufactured by Foster and Freeman, Ltd., of England, is an example of a valuable forensic tool that can be potentially hazardous when used improperly. The device is designed to assist in the detection of indented writing in documents. The technician applies an electrostatic charge to a plastic film-coated document, which attracts cascaded or aerosoled toner to the indentations in the document for examination. A permanent record may be obtained by applying an adhesive film.

The device is safe when properly installed and operated. However, the following potential hazards could result in personal injury: high voltage from the corona unit, ozone generated by the corona unit and, to a lesser degree, inhalation of toner particulate.

High Voltage

A charge is imparted to the document from a handheld corona unit at an 8kV potential. Additionally, when the aerosol generator is in operation, the nozzle is at an 8kV potential. The unit itself operates at 110v AC (in the United States) with a 24v DC supply internal to the machine. The manufacturer's safety instructions should be followed closely to prevent electric shock. These precautions include not touching the corona wire, resting the unit face down on a noncon-

ducting surface, for example, a plastic board, and avoiding contact with the nozzle when the unit is in operation.

Additional safeguards are also recommended. Frequently inspect the ground wire to the corona unit to ensure that it is always properly attached. Place a "This Side Up" caution sign on the handheld unit so that the wire side cannot be accidentally grasped if it is facing away from the operator. Inspect the power cord frequently and ensure that it is connected to a grounded receptacle. Recommend to the manufacturer the possibility of installing an interlock switch to de-energize the nozzle when the cover is raised.

Ozone

Ozone is created by any high-voltage corona through ionization of atmospheric oxygen molecules. It is a colorless gas with a sharp, characteristic odor. It can be smelled at concentrations at or below the Occupational Safety and Health Administration's (OSHA) permissible exposure limit. This gas is extremely irritating to the upper- and lower-respiratory tract, causing local irritation of the eyes and mucous membranes. Pulmonary edema could also result from high exposures. Reported systemic effects can mimic those of ionizing radiation and may cause chromosomal damage.

Symptoms of overexposure include irritation of the eyes, dryness of nose and throat and cough. Higher exposures may cause headache, upset stomach, pain or tightness in the chest, shortness of breath and tiredness. Severe overexposure can result in lung damage and death.

The OSHA standard for ozone is 0.1 ppm averaged over an 8-hour workday. The American Conference of Governmental Industrial Hygienists has established a short-term (15 min) exposure limit of 0.3 ppm. These limits are believed to be safe for most workers with normal health.

Sampling was conducted to determine concentrations of ozone in the immediate area of the handheld corona unit and to determine an approximate emission rate for ozone from the handheld unit. Tests were conducted using Gastec-Bendix detector tubes and a 100 ml calibrated handpump. The tubes are certified by the National Institute for Occupational Safety and Health (NIOSH) for ozone with a sampling and analytical error of plus or minus 25%.

Table 1 shows the results of sampling. The first group of data lists ozone concentrations in the vicinity of the wand while placed face up on a workbench. The second group of numbers reflect results of samples collected

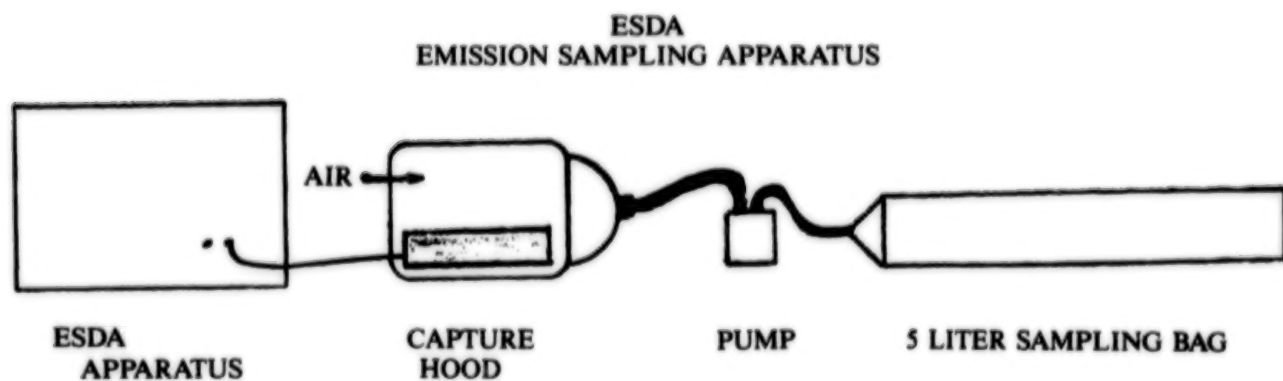


Figure 1. ESDA emission sampling apparatus.

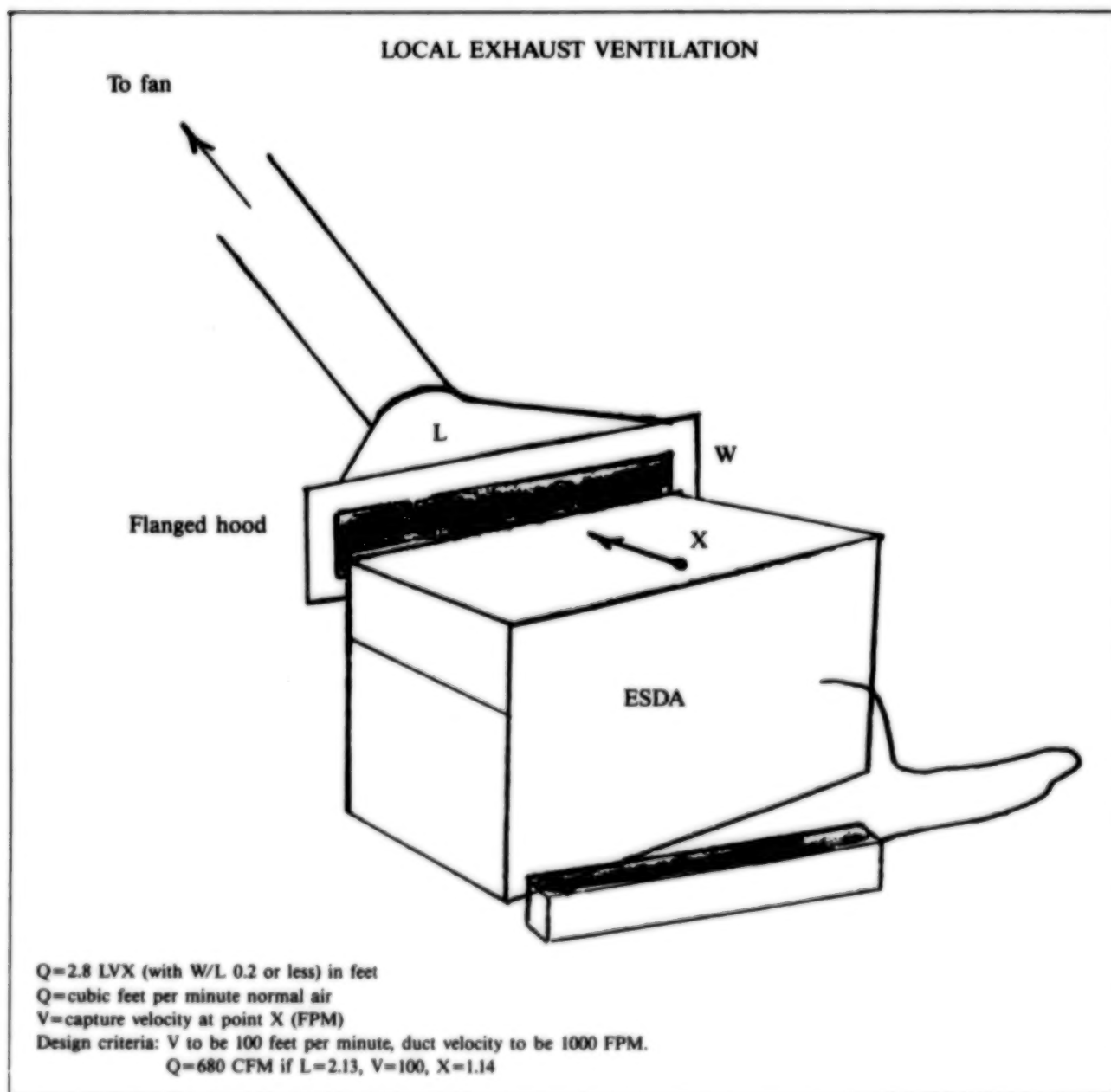
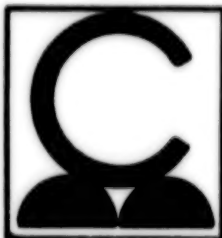


Figure 2. Local exhaust ventilation.



Coates

Product safety data sheet

PRODUCT Negative Powder Toner/
Developer

DATE 30th August, 1978

RP0201

No. R51

HEALTH HAZARD

This product is formulated on materials that are not thought to be harmful, or are not present in sufficient quantities to be harmful, if used properly under normal conditions of good industrial hygiene.

Inhalation: No danger in normal use.

Ingestion: Substantially non-toxic, but if swallowed call physician.

Skin Contact: Not injurious. Can be brushed off or flushed with water.

Eye Contact: Does not attack eye tissue. Flush with water to remove particles.

FIRE HAZARD

Flash Point Not applicable

Designated highly flammable No

Extinguishing media Dry chemical or foam may be used

Storage: Store in a well ventilated area.

Spillage: May be swept up. Use face mask to avoid dust inhalation.

Disposal: Ensure conformity with local authority regulations.

Foster and Freeman

Signature _____ Date _____

Figure 3. Product safety data sheet.

Table 1. ESDA OZONE SAMPLE RESULTS

I. Vicinity of Wand		
Operating Time	Location	PPM
30 sec	6 in	0.5±.13
10 sec	1 in	3.0±.75
10 sec	1 in	1.0±.25
II. Emission Rate/10 Second Operation		
PPM	Mg/M3	Mg/Operation
1.75±.48	3.44±.86	.017±.004
2.0 ±.5	3.93±.98	.019±.004
1.25±.31	2.45±.61	.012±.003
1.00±.25	1.96±.49	.009±.002
1.00±.25	1.96±.49	.009±.002

Arithmetic mean = .013 mg/operation

mg/operation = ((ppm*mw)/24.45L)* .005M3

mw = molecular weight of ozone = 48

24.45 = liters per gram-mole of gas at STP

with the sampling train shown in Figure 1. A 10-second operation time was postulated, so the wand was placed in the hood and switched on for 10 seconds while the pump evacuated the hood air into a 5-liter gas sampling bag. The air in the bag was then sampled with the detector tubes and an emission rate per operation calculated. This was repeated five times. Ozone decay or destruction mechanisms were not taken into account. These mechanisms include chemical reactions with many materials—solid and gaseous, thermal decomposition, and normal self reactive decay ($O_3 + O_3 = 3O_2$).

The results indicate that concentrations of ozone in the immediate area of the wand can exceed short-term exposure limits (0.3 ppm). The emission rate calculated for a 10 second operation ranged from .007 mg to 0.023 mg with an arithmetic mean of .013 mg. No explanation for the wide range of values is postulated, but variables may include sampling and analytical error and ozone emission fluctuation caused by voltage fluctuation. It is prudent to assume that the highest value may be produced during normal operation.

Inhalation of air in close proximity to the wand operation of the ESDA in small unventilated rooms or lengthy operation in any unvented room could pose a health hazard. Therefore, it is recommended that the unit be switched on only long enough to energize the subject document and then switched off. Ideally, a small local exhaust system or laboratory hood should be used to remove ozone from the operator's breathing zone. Usually a laboratory hood is available in forensic laboratories. However, all flammables and combustibles should be removed from the hood before use.

Figure 2 is an example of a local exhaust hood with the advantage of low air flow. At a minimum, room dilution ventilation that provides 10 air changes per hour is recommended.

If ozone overexposure is suspected, the operation should be stopped and sampling conducted to determine if overexposures are present. Exposed personnel should also be examined by a physician. Respirators may be used as an interim protective measure while corrective measures are being taken. Consult with the organization's safety and health personnel.

Toner

The toner and glass beads used in the ESDA are similar to materials used in office copy machines—usually a mixture of carbon black, amorphous silica, zinc stearate, iron particles and inert plastic polymers. Figure 3, a safety data sheet supplied by the manufacturer indicated that the material is innocuous. As a precaution when using the powder cloud option, however, the ventilation as described above will prevent inhalation of particles, as well as contamination of the laboratory with fugitive dust.

CONCLUSION

Safety and health programs in the forensic or crime laboratory can prevent injury, illness and costly accidents. The ESDA when used safely is a valuable tool. Potential hazards include high voltage and ozone. Proper operating procedures, including frequent inspection of high-voltage elements and ventilation to remove ozone from the operator's breathing zone are recommended.

SUGGESTED READINGS

- Allen, D. B. (1978). Xerox Material Safety Data Sheet, 1075 Toner, MSDS 0023, Xerox Corp., Rochester, New York.
- Allen, R. J., Wadden, R. A. and Ross, E. D. Characterization of potential indoor sources of ozone. *Amer. Ind. Hyg. Assoc. J.* 39:466-471.
- Gallo, C. F., and Castle, G. S. P. (1978). Parametric study of ozone generation by coronas, *IEEE Transactions on Industry Standards*, IA-14:1:Jan/Feb.
- Mackinson, F. W., Stricoff, R. S. and Partridge, Jr., L. J. (1981). Occupational Health Guidelines for Chemical Substances. DHHS Pub. 81-123, Washington, D.C.
- Negative Powder Toner/Developer (1978). Coates Product Safety Data Sheet No. R51, London, England.
- Occupational Diseases, A Guide to Their Recognition (1977). DHEW Pub. 77-181, Washington, D.C.

TYPEWRITER IMPRESSION COMPARISON STUDY CONSIDERATIONS

Arthur Schlang

Imagery Associates
Consultant Engineers
Coram, New York

The Problem

An expert document examiner usually has little difficulty in stating, to a high degree of confidence, that a questioned document was or was not created on some specific poor- to medium-grade typewriter. However, when the suspected device is a high-quality, well maintained office machine, it is often impossible for that examiner to render any meaningful opinion.

The FBI is concerned with this problem and has instituted a research effort to ascertain if, by advanced methods of computer analysis, singular characterizing typewriter "signatures" can be discerned. This program was placed under the direction of Michael G. Noblett of the Document Research Group. Tentatively, there are encouraging indications that the sought for signatures exist and work is continuing to refine the computer algorithms and to expand their scope.

The initial hardware and software work was performed at the Amecom Division of Litton Systems where I was the manager of Simulation Studies. Algorithmic optimization is now being performed at the FBI Headquarters in Washington, D.C. I am still associated with the program, but as a private consultant.

Computer Entry

The questioned document data is entered into computer memory using a precision electromechanical scanner with a resolution of 600 lines per inch horizontally and vertically. Thus a typical 8-1/2 x 11 inch document exhibits 33,660,000 picture elements each accommodating 256 shades of gray. For economy, the initial computer chosen for the research effort had limited main memory and disk space and we are forced to use documents with dimensions of 3 x 10 inches. However, more than 800 characters were jammed into the constricted area, which is close to that encountered on normal size pages. As of the writing of this dissertation, main memory and disk space have been significantly increased, permitting us to pursue the processing of normal size pages in the future.

Separation of Lines of Text

Once the document gray-scale image is installed in computer memory, it is processed to remove nontextual data typified by logos and signatures. For illustration, Figure 1 is a contrived military message to which various corporate logos have been affixed. The text was purposely typed with about a 2.5° tilt and a signature

was added that invaded a line of text. Figure 2 illustrates the page residue after textual removal. Observe the characters left behind that are touched by the signature strokes and the dotted lines adjacent to the bottom left logo. This latter effect was caused by the logo buckling away from the document surface. Also, notice how tolerant the algorithms are of document tilt.

The algorithms, in effect, place a rectangle around each text line, thereby excluding nontextual material. No restriction is placed on intertext line spacing and offsets relative to top, bottom, left and right page edges. Additionally, variable text line lengths and arbitrary fonts are fully accommodated. This performance is achieved using a computer analysis regimen employing methods of statistical inference.

Character Stripping

Once lines of text have been delineated, the characters are separated, one by one, for individual analysis. A contour following algorithm is employed that strips characters, even if they vertically overlap with their neighbors. Occasionally adjacent characters fuse but the pair is separated as if it were one symbol. In the past, fused entities were discarded because they consumed excessive computer memory. With the expanded computer capabilities, such anomalies will now be processed since they do represent aspects of typewriter signature effects. A rather unique capability of the contour tracking regimen is that it is not confused by vertically disjoint characters (that is, *i*, *j*, *;*, *;*, *?*).

Figure 3 illustrates a typical stripped character and requires explanation. The dots represent spacings on the actual document of 1.67 mils. The vertical and horizontal unevenness is introduced by a standard printer being employed as a graphics device. A true graphics printout is planned for the future and would not exhibit the apparent anomaly. Alphabet letters are used to signify the gray level of each picture element. In order not to overly clutter the presentation, each letter represents five adjacent shades of gray. The dots denote the least six shades of gray, lower case *a* to *y*, the low 125 shades, and upper case *A* to *Y*, the higher 125 shades (256 in all). An analog threshold, which can be set by the operator, is employed to suppress dirt effects without compromising character integrity. In Figure 3, that threshold is 90, which causes all levels below that value to become dots. This is a somewhat confusing display and requires getting used to. There appears to be no better way of portraying shades of gray to the required resolution. The highly nonlinear human eye tends to suppress small variations in gray

01

RR

UUUU

DIA WASHINGTON DC//RSO//

USDAO BONN GE

INFO USCINCEUR VAIHINGEN GE



UNCLAS

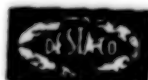
SUBJECT: MESSAGES DURING MINIMIZE

1. MINIMIZE IS A CONDITION IMPOSED UPON USERS OF TELECOMMUNICATIONS CIRCUITS DURING PERIODS OF CRISIS OR EXERCISE. ITS PURPOSE IS TO CONTROL TRAFFIC IN ORDER TO FACILITATE THE PROMPT TRANSMISSION OF ESSENTIAL TRAFFIC.

2. MINIMIZE MAY BE IMPOSED WORLDWIDE OR ON A SPECIFIC GEOGRAPHIC AREA.

3. DURING MINIMIZE, MESSAGE DRAFTERS AND RELEASERS WILL REVIEW ALL MESSAGES TO ENSURE THAT ELECTRICAL TRANSMISSION IS ESSENTIAL, THAT THE LOWEST PRECEDENCE CONSISTENT WITH SPEED OF SERVICE OBJECTIVES IS USED, AND THAT THE WORDS "MINIMIZE CONSIDERED" ARE PLACED IN THE SPECIAL INSTRUCTIONS BLOCK AS SHOWN BELOW. SEE PARAGRAPH 3-13.

NNNN



DIA JCSMC MCEB J3

GENERAL  ELECTRIC

MR CONTROLLER, CHIEF MESSAGE
WATCHER, 53337, 16 NOV 78

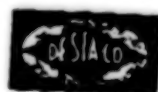
MINIMIZE CONSIDERED

I.M. CLEARED RSO, 53937

UNCLASSIFIED

A handwritten signature in cursive script, likely of the person responsible for the message.

Figure 1. Contrived military message to which various corporate logos have been affixed.



Arthur K. Lang

Figure 2. Page residue after textual removal.

Image Libraries

In order to perform the task of forming the attribute tables, a dual library approach is implemented. The first character to be stripped from the page is designated Character 1 and its image is simultaneously copied into the Matching Library and the Averaging Library. The second stripped character is compared against the single Matching Library entry for similarity. If the same, the second character is also defined as Character 1, and it is summed to the counterpart image in the Averaging Library. Its measurements are also statistically combined with those of the counterpart. If, however, the second character is different it becomes Character 2 and it is simultaneously entered into both libraries but in empty memory positions. The third character must now be compared against two library entries. This process continues until the entire page is scanned. Final statistical processing is now effected since the total number of characters in each category is known and all of the Attribute Tables are formatted.

The question of what constitutes a match and what does not is important because no two characters in a category are ever identical (or rarely so). It is beyond the scope of this paper to detail the method employed but, in essence, a number is generated that measures the goodness of fit. The lower the number, the better the correlation. A threshold is established so that a match is indicated if the number is less than a prescribed value. This is an oversimplification of the actual process but is sufficient for this discussion.

The choice of the threshold is critical to the performance of the algorithmic efficacy. If a high threshold is selected, all characters in a category are combined regardless of aberrations. Concomitantly, however, a high threshold invites one character to be misinterpreted as another (a substitution is definitely unacceptable). A very low threshold precludes all substitutions but renders the system to be overly critical and creates superfluous library categories for minor differences in character formation. We have chosen a threshold value that apparently is impervious to substitutions and creates few superfluous categories. This claim must be qualified. For certain fonts, upper case 0 and numeral zero are virtually indistinguishable even to the human eye. Another example, depending on font, is lower case l and numeral one.

What has been described is a self-teaching regimen where the libraries start empty and grow to meet the needs of the document. The system does not know the name of a letter B, only that it is a symbol that it has or has not encountered before. This is a very important feature of the system since it automatically accommodates any font without operator intervention.

Cull and Merge

The operator is given the option of examining the printed Attribute Tables and performing post-recognition editing. If some symbol has a low popula-

```

.....vADFFHJHFCAutr.....
.....vQMOQRSSSRSTSSSSRQOOKIFAt.....
.....AKQTSSTTTSSSTSTSSSSSTSSSRPJv.....
.....uHPSUTSTTTTTTTTTTTTSTTTSTTTSTNv.....
.....uMSRSTTTTUTUUUUUTUUUUUTTTTUTUSRI.....
.....vNTTSSUUUTSQQNMNMNOSSSSUUUTUSSM.....
.....JRTTTSUTPKGBYw...routu1EKANTUTTRN.....
.....APTSTTUQF1.....thRSSSSM.....
.....HQTTTTDC.....tLSTTRJ.....
.....LQTTUPB.....JRTTRH.....
.....NRUTSKu.....FSRSRH.....
.....OSTTRH.....IQRSRE.....
.....LSTTSLu.....DOSSOB.....
.....GSTTTQE.....JSRLt.....
.....uOSTSRQKAr.....yv.....
.....IRTTTTSGHJy.....
.....uLSTSSSTTSGHJFAs.....
.....vMSSTTTTTTTTTTSGHJEW.....
.....vKQSTTUUTUSTTSSOPMGBus.....
.....rCNSTUUTTTSSSTSSSSONMBr.....
.....rBHPSTTUSSTSTTTTSTROWu.....
.....1CIKNORTSTTTTTTTTTTSQJu.....
.....r1CHMORTUTTTTTTSTSOC.....
.....uFLORUTTSTTSRE.....
.....r1DIOSTUTTSTOC.....
.....y1.....rENTUTUTSM.....
.....KRGHq.....yKSTUTSOW.....
.....BTERF.....t1TSTRG.....
.....JRSTSL.....1PUTORK.....
.....KRTSTH.....LTTSGOR.....
.....KRRSSNr.....KTTSQL.....
.....JRSSSu.....1OTSTQJ.....
.....JSTTHu.....HSTSSH.....
.....JRTTQy.....FPTTTTRE.....
.....LSTTUTIFBvT.....u1JRTTRSTNt.....
.....JSTTUTTRPMLIFBvvt1v1ACHKOSTTTTTTRE.....
.....FRTTTTUUUUTTRGPPDGGORTUUUTSTTTSI.....
.....yGTTTTSTTTTTTTTTTTTUUUUUTTTTSUUSIv.....
.....ISUUUJUTTTTTSTTTSTTTTTTUUUTQEs.....
.....DKNRRTUUUUUTTTSSSTTTTUUUURNC.....
.....uBQIKMPRTTSSRRSSTTSSRPMD.....
.....u1ACEDEFFFEFBY1s.....

```

Figure 4. The file name is IBMSCRIBE2.MKO.082184
Document reference = 123456
Date = Thu, Mar 14 1985 Time = 15:29:12
Total characters = 697
Analog Noise Thresh = 90
Number of Categories = 88
Maximum number of categories = 99
Identity = 20 Frequency = 10
Width = 38.50 Stdev = 0.8498
Height = 43.10 Stdev = 0.7379
Lead Pitch = 62.50 Stdev = 0.7071
Trail pitch = 59.00 Stdev = 0.8165
Voffset = 22.40 Stdev = 2.8363
Tilt = 0.7771 Stdev = 0.0373

tion, the Attribute Table is no better than the raw image and the operator may cull that data as being statistically unreliable. The operator may also conclude that the system was overly critical and created two categories on the same symbol. The operator may merge such data into one category. This cull and merge capability compensates for a conservative threshold level, which is desirable since the purpose of the system is to obtain an accurate representation of each typewriter character, not to interpret all variations of letter *B* as one symbol. This is a different mission than pursued by the optical recognition community, which is not interested in physically analyzing characters, only in identifying them.

Observe that the system now assists the document examiner as a tool. It has not and never will replace the document examiner.

Comparison of Questioned Documents

Up to now the formation of Attribute Tables has been described as the means chosen to categorize a document. Documents are compared by correlating their Attribute Tables to arrive at a statistical conclusion (with confidence level) that the two entities were or were not created on the same machine. Algorithms to perform this task have now been defined and will be implemented this year.

The measurement data (height, width, etc.) will be correlated employing methods of statistical analysis of variance. The software for this work is commercially available and probably will not have to be written.

Symbolic correlation of the Attribute Table images will be accomplished by forming difference images to accentuate dissimilarities. Prior to this task, both sets of imagery require amplitude normalization. For now, human interpretation of the difference images is planned. Algorithms will be investigated to assist the examiner in interpreting those products.

Rarely is character 15 of one Attribute Table set the same as character 15 of the other set and such designations become meaningless. Software requires writing that matches the tables of both documents and is not self-teaching, as are the previous matching procedures.

The Future

The present investigatory phase is being accomplished on conventionally structured computer architecture. This approach is necessitated by the requirements for versatility and, as a consequence, the processing time per document is impractically long for operational use. Should the algorithms prove to be effective, and there is cautious optimism that they will be, dedicated hardware can be constructed to greatly decrease processing time, but at the cost of not easily allowing system modifications. These tradeoffs are not unique to this application. Our simulation studies will continue on the present computer until we are certain that the algorithms are perfected.

A preliminary investigation has indicated that the newer concepts of systolic array processing would fit the needs of this application nicely.

LASER SCANNING OF INKS

D. Varshneya

Babcock and Wilcox, Alliance, Ohio,

L. A. Jeffers

Minerva Research Corporation, Alliance, Ohio, and

M. G. Noble

Federal Bureau of Investigation, Washington, D.C.

Luminescence imaging is routinely used in the investigation of suspected documents to identify alterations, erasures, additions, etc. This technique is based on the fact that different inks and papers luminesce differently when excited by a suitable light source. Thus, a certain ink and paper combination has a unique luminescence spectral distribution that is different from another one, not only in the spectral shape but in total intensity as well. This property is exploited in the analysis of documents, which in principle can reveal alterations and/or additions.

Systems currently used (Figure 1) excite luminescence from a document with a wide band of wavelengths and detect this luminescence over a large wavelength range. Therefore, much of the potentially useful information available from the spectral distribution is lost. Although such a system is useful, it is recognized that major performance improvements may be achieved using currently available lasers and by exploiting the capabilities of digital data processing/acquisition. A combination of such capabilities has been used in the development of the Luminescence Imaging Document Analyzer (LIDA), which provides high sensitivity, specificity, versatility and ease of operation.

Luminescence can be categorized either as fluorescence or phosphorescence depending on the characteristic time delay between excitation and emission. Fluorescence occurs within 10^{-8} sec of the excitation, while phosphorescence time constants range from milliseconds to seconds. An additional feature of LIDA is its ability to distinguish between fluorescence and phosphorescence.

Luminescence spectroscopy is a powerful and sensitive analytical tool. As in other forms of spectroscopy, each substance has its own characteristic spectrum or signature. Since luminescence involves an absorption and subsequent remission of light, the signature is a function of both the exciting (λ_1) and the emitted (λ_2) wavelengths. This two-dimensional dependence adds to the specificity and instrumental complexity of luminescence spectroscopy.

This additional complexity has been dealt with by either: (1) fixing λ_2 and plotting intensity as a function of λ_1 , thus generating what is referred to as the excitation spectrum or (2) fixing λ_1 while plotting the intensity as a function of λ_2 . In this case, the result is referred to as the emission spectrum.

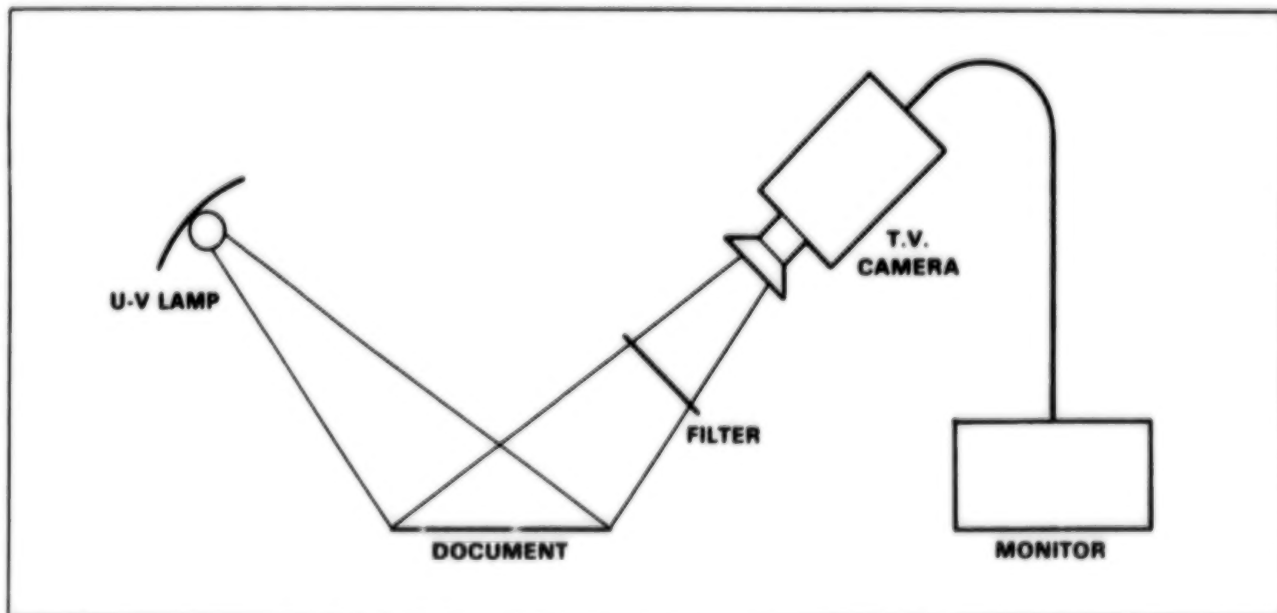


Figure 1. Fluorescence imaging.

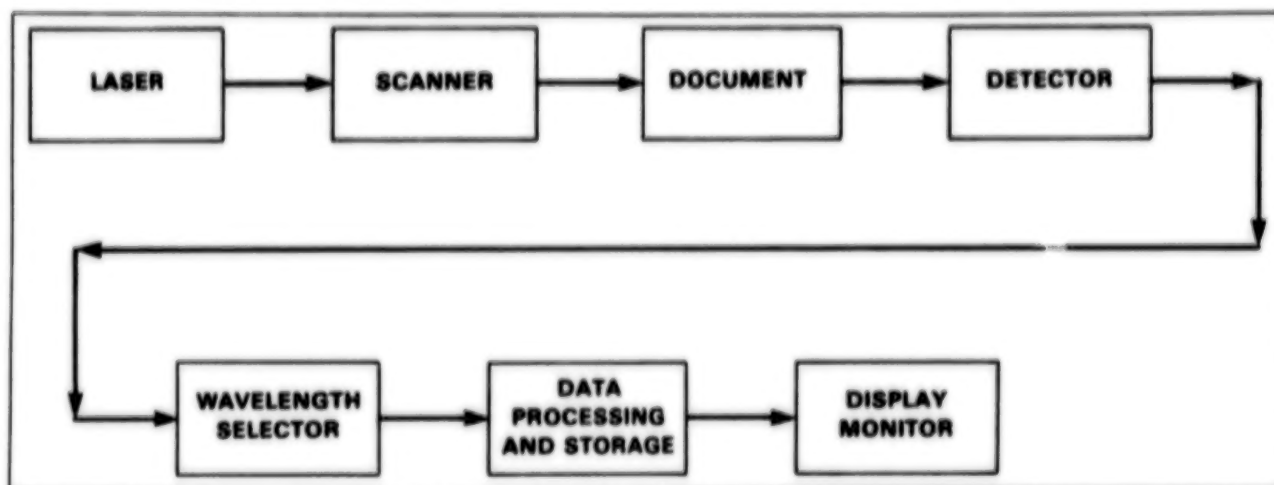


Figure 2. Major components of LIDA system.

The full information content can be presented as contours of constant intensity on a plot of λ_1 versus λ_2 .

In previous luminescent systems for document analysis, none of the potential spectral specificity is realized because excitation is by a fixed wide band of wavelengths, $\Delta\lambda_1$, and the emission is detected over a second fixed wide band, $\Delta\lambda_2$. Furthermore, no distinction is made between fluorescence and phosphorescence.

In the LIDA system, major improvements over the previous system have been made. The purpose of this paper is to describe, in detail, the newly developed system.

SYSTEM DESCRIPTION

Summarized Description

Figure 2 is a block diagram showing the major components of the LIDA system. A laser beam is raster scanned across the document to be inspected. A portion of the laser light that is absorbed by the paper and ink is emitted again as luminescent light. The luminescent light occurs at wavelengths longer than the exciting laser wavelength because a portion of the absorbed energy is converted directly to heat rather than being reradiated. Because of the multiplicity of modes for conversion to heat the luminescent emission occurs over a band of wavelengths. The intensity of emission as a function of the wavelength provides a signature or spectrum that is characteristic of the material luminescing.

The luminescent light is passed through a wavelength selector and onto a detector. The wavelength passed onto the detector is chosen so as to maximize the difference between the luminescence from the inks and the paper, between one ink and another, between erased and nonerased areas, etc.

The output of the detector goes to the data store and processor. The processor digitizes, stores and conditions the signal to make it compatible with display on a standard monitor.

The monitor displays an image of the document as seen in the luminescent light within the wavelength band selected. Any alterations in the document, such as erasures and sections added with another ink source, will stand out in the displayed image because of the differential luminescent response.

Complete System Description

Figure 3 is a block diagram of the complete system. The arrows attached to the various components indicate interconnections with the computer, which provides automatic control of the system as well as data acquisition, management, enhancement, storage and display.

Only one laser is used at a given time. Four lasers are included in the LIDA (Figure 4) and there is provision for adding a fifth so that the excitation wavelength can be changed. The lasers are all aligned so that any one of them can be selected for use by the positioning of a single laser selecting mirror (Figure 5). This mirror is mounted to a rotatable shaft to which a 6-inch diameter wheel is attached. A precision set screw that nests in notches in the wheel ensures that the mirror is properly aligned with the incoming laser beams. The mirror position is monitored by the computer using magnets and reed switches so that the identity of the laser used may be automatically added to the data record.

The laser select mirror directs the laser beam vertically up into the excitation/collection table. A small laser mirror at 45° to the table redirects the beam onto the center of a planoconvex lens. The lens focuses the beam on the document through a pair of orthogonal, mechanically driven mirrors. The mirrors are used to scan the laser light beam on the document. The computer controls the mirror position to produce a raster

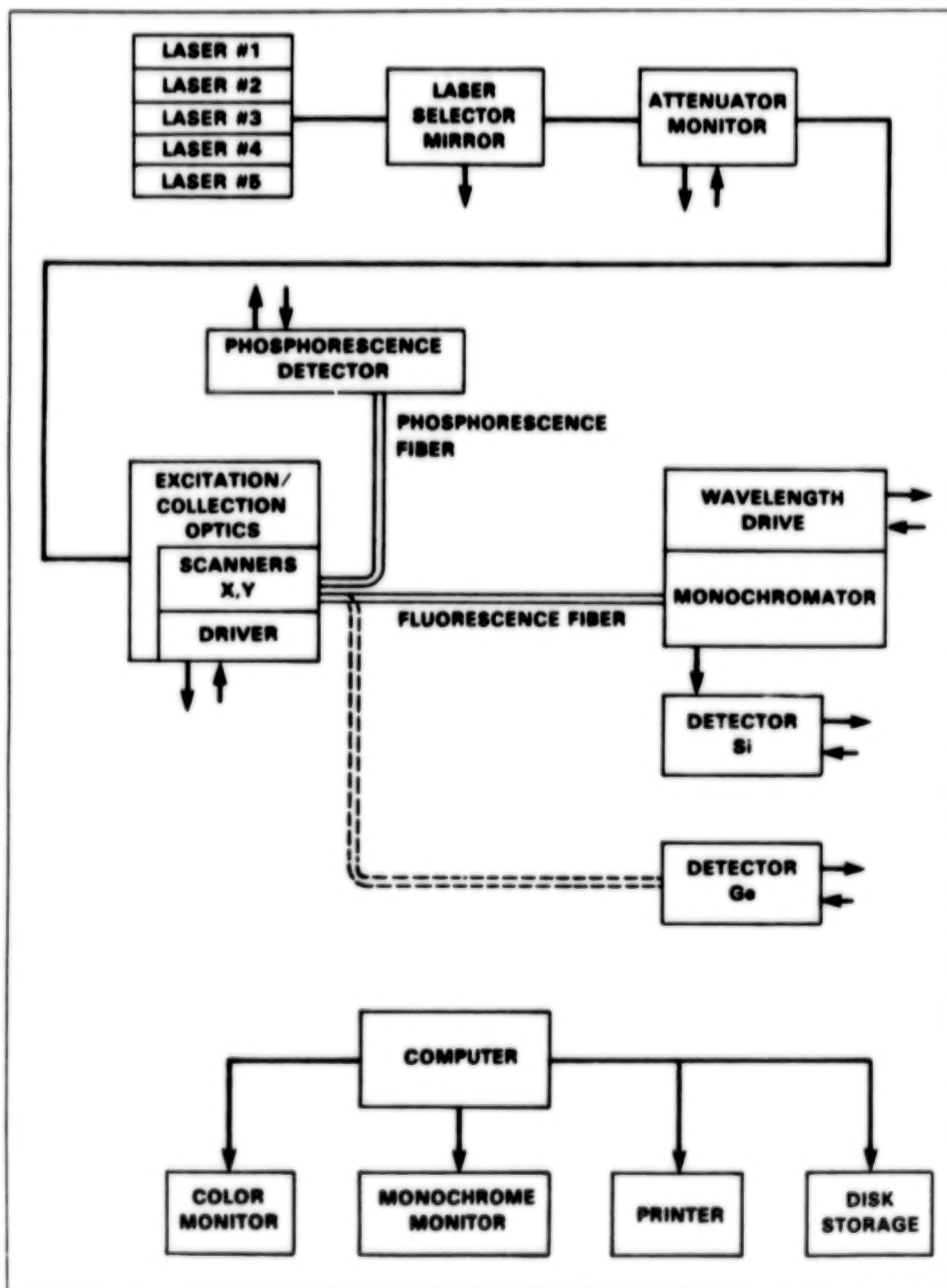


Figure 3. Block diagram of LIDA system.

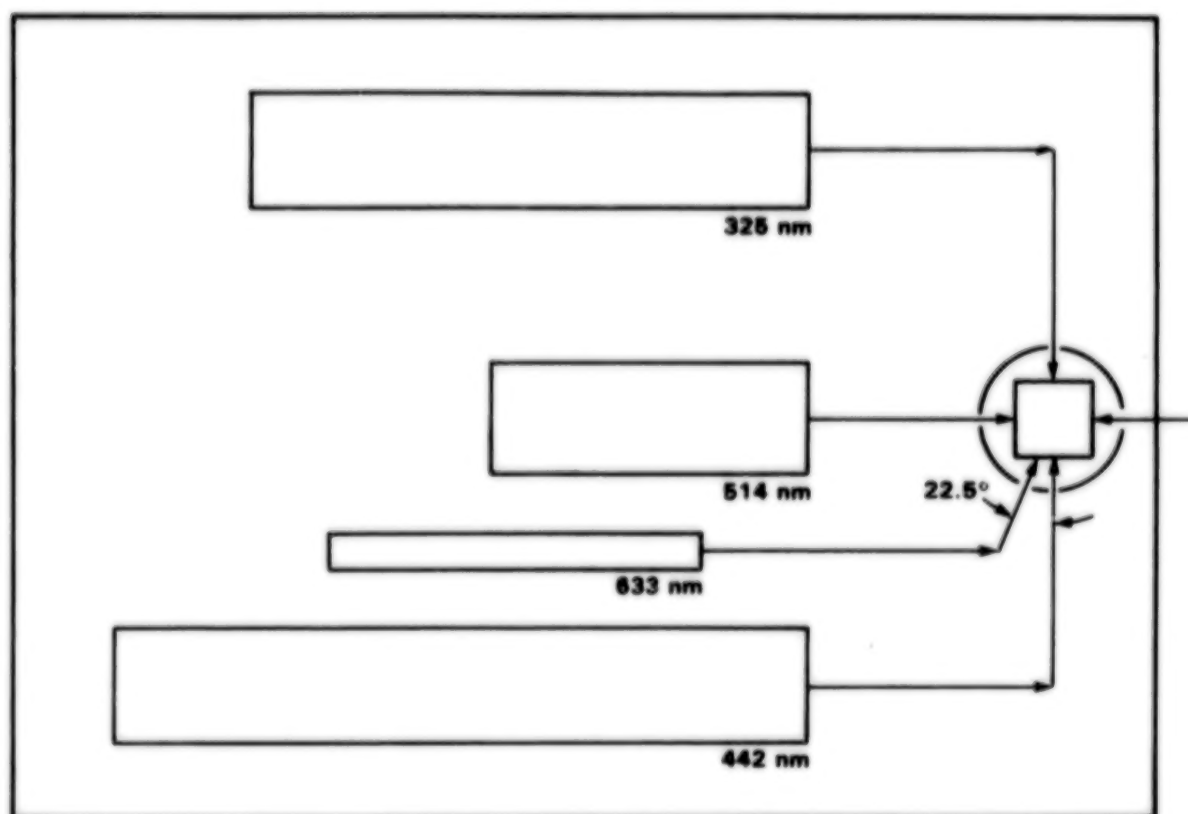


Figure 4. Laser table layout.

scan of the document area. Light scattered from the sample document is collected by the same scanning mirrors and the planoconvex lens. The lens approximately collimates the collected scattered signal on a concave mirror. The combined effect of the planoconvex lens and the concave mirror is to form an image of the document at approximately the focal point of the mirror.

Because of the potential for irreversible bleaching or burning of the sample at the high-power density focused laser beam spot, and because of nonlinear fluorescence response at high-power densities, LIDA includes a tunable attenuator and a laser power monitor. The output of the monitor is input to the computer and included with the luminescence data.

Figure 6 shows the major components of the excitation/collection optical system. For simplicity, one of the scanning mirrors has been omitted from the sketch. Also omitted from the sketch is the laser power monitor, which may be driven into position to measure input light power and/or block the incident beam except when a scan is in progress.

The same mirrors that provide the laser scan also scan, simultaneously, the area viewed by the photo-detector. Having the detector field of view focused to

a small spot that follows the scanned laser spot provides a very important advantage (for example, fluorescent light can be very efficiently coupled through an optical fiber into a monochromator for wavelength selection before passing onto the detector). The fluorescence collecting fiber is positioned in the image plane of the collection optics system (a planoconvex lens and a concave mirror) at the location of the focused laser spot. The phosphorescence collecting fiber views an area immediately adjacent to and trailing the laser spot. This fiber therefore views the spot at which the laser was focused some short time before. The actual time delay depends on the scanning rate.

Figure 6 shows a cylindrical lens between the focusing mirror and the fibers. The purpose of this lens is to minimize the astigmatism produced by off-axis operation of the concave mirror. A slot is provided in the mount of this lens to mount color filters that are used to extinct the reflected laser light when the system is not used in the monochromator mode.

Figure 3 shows the fluorescence fiber that provides light input to the monochromator. The dashed line symbolizes the possibility of going directly to the detector instead. This mode of operation sacrifices the wavelength information to provide more signal, since

all wavelengths are passed simultaneously to the detector. Although Figure 3 shows a silicon detector mounted to the monochromator and the germanium detector operating in direct view, the detectors can be used interchangeably.

Operator interface to the system is the keyboard of an IBM personal computer, which provides overall system control as well as acquisition, management and display of the data.

Results are displayed as false color images on a color monitor. A second monochrome monitor displays the menu-options and other system information for the operator. At the conclusion of an investigation the data are stored on a floppy disk and a printer provides a permanent listing of all pertinent information for inclusion in the case file.

CAPABILITIES OF THE SYSTEM

The capabilities of the LIDA system are categorized in two modes of operation. These are the imaging mode of operation and the spectral mode of operation.

Imaging Mode

The imaging mode consists of the following options:

- **Reflectance**—With this option, one can sample a 6 x 4 inch portion of a document at the excitation laser wavelength. The image of the document is formed from the reflected light and displayed on the color monitor.

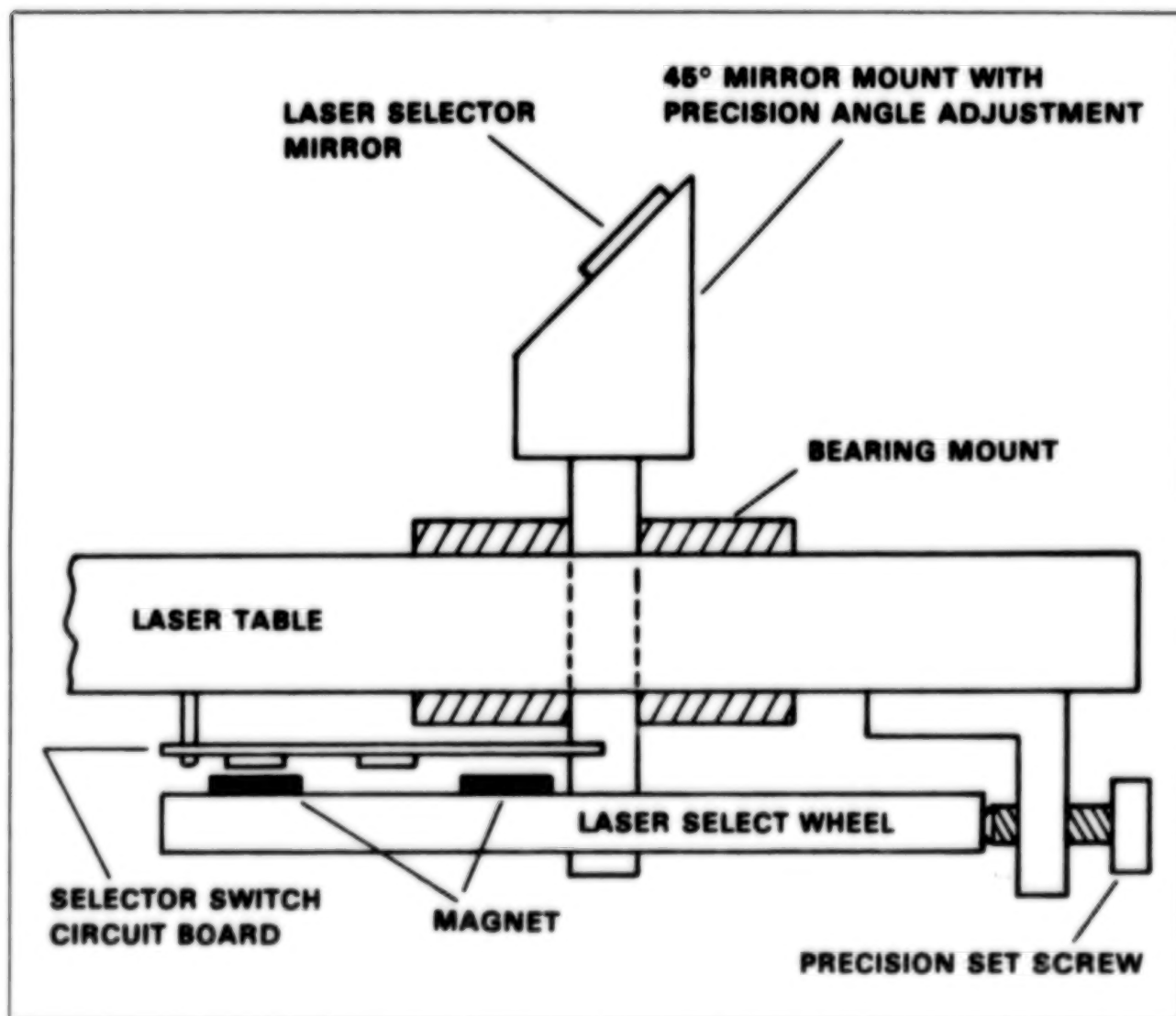


Figure 5. Laser select mirror.

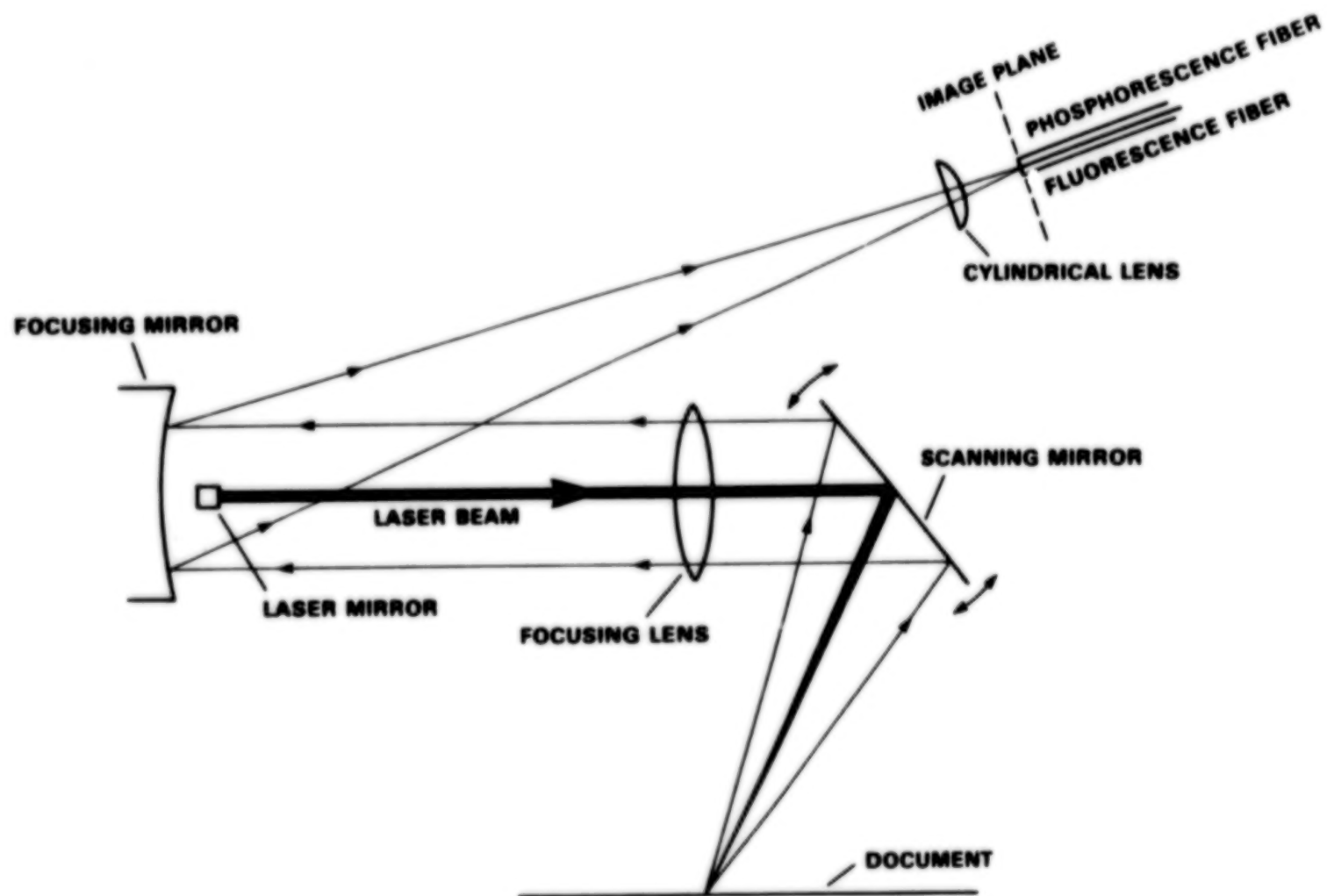


Figure 6. Excitation/collection optical system.

- **Fluorescence**—The signal from the document is transmitted through the monochromator, which separates individual luminescent colors onto a detector while filtering out the laser wavelength. The color monitor displays the image of the document as observed in the fluorescent light within the wavelength band limit of the monochromator.
- **Integrated fluorescence**—The signal from the document bypasses the monochromator and is detected without conditioning by a photo-diode. A laser filter is used in the output light signal to extinct light at the laser wavelength. Thus, the image of the document contains information from a wide band of wavelengths. This provision gives results similar to that obtained by the first generation system.
- **Integrated phosphorescence**—This is similar to integrated fluorescence except that the image is formed at a wide band of phosphorescence wavelengths.

For each of the above options, there is a choice of four different lasers operating at 325 nm, 442 nm, 448 nm and 514 nm, with the capability of adding a fifth one at 633 nm. Thus, luminescence from a document may be excited by light at any one of the five wavelengths. Five scanning rates allow the operator to enhance the detector sensitivity. The longer the scanning rate, the higher the sensitivity and image resolution. An option is also provided to increase the sensitivity by amplifying the light signal. Selection of the amplification is made from four detector gain levels provided. To identify and compare subtle areas in the document, the image can be magnified up to six times the initial size in six discrete steps.

Spectral Mode

In this mode of operation, a spectral distribution plot (that is, $I(\lambda)$ versus wavelength in one specific region of the document) is obtained with the following added features:

- $I(\lambda)$ versus λ may be obtained for the 400 horizontal scan lines that define the system's 6 x 4 inch scan area on the document.
- There is a choice of six widths for each of the 400 lines ranging from 1 to 6 inches.
- Once the start (λ_s) and end (λ_e) wavelengths are chosen (span of the scan = $\lambda_e - \lambda_s$), the system automatically selects the wavelength step size. The minimum span is 50 nm and the maximum (1000 - λ_s) nm.
- Five scanning rates are provided. The minimum scan rate is 52 sec. The detection sensitivity increases with longer scan rates.
- There are four signal amplification stages provided in the detector electronics. Sensitivity can also be increased using these gains.

SOFTWARE CAPABILITIES

The system software capabilities provide an operator with several options:

- Menu-driven programs
- Record of laser-select identity
- Monitoring laser power and storage of result
- Option to plot intensity versus wavelength
- Storage of data on floppy disk
- Permanent listing of document analysis with comments
- Loading stored data from disk.

For all the above options, the system is accessed through a keyboard of a personal computer that also provides overall control.

The operator logs into the system to begin the analysis of a document. A menu appears on the monochrome monitor, which allows the operator to follow one of the four options discussed previously. Selection of any one of the options leads the operator to another set of menus. Capabilities are provided at each stage to exit or access other options. These programs, therefore, provide ease of operation and are the key features of the LIDA system.

Before a scan is made, the computer automatically records the selected laser used to excite luminescence from the document. An option is provided in the software to monitor the laser power and store the power reading if desired. This information is printed after the completion of the document analysis.

After each scan, options are provided to obtain a plot of intensity versus wavelength for any part of the scanned document area. This feature in the LIDA system is very powerful because it enables the gathering of additional information that could not be obtained with first generation systems.

At the conclusion of an investigation of a document, the data may be stored on a floppy disk. An option is provided in the software to obtain a permanent listing of all system parameters, document identifications, operator comments relevant to the document scan and other pertinent information (type of laser, laser power, etc.). For this purpose, a printer is used so that the information may be included in the case file.

SUMMARY AND SYSTEM SPECIFICATIONS

A system to detect alterations, additions and erasures on a document has been designed, developed and fabricated. By exploiting the capabilities of laser beams and digital data processing, the LIDA system has high sensitivity in detection, wavelength definition, and ease of operation. The software capabilities of the system provide an operator with numerous options. These programs and options allow easy access to the system with

the ability for data manipulation, enhancement and management.

The system specifications are as follows.

Maximum document size — 11 x 14 inches

Document thickness — .001 to 3 inches

Image scan area — 6 x 4 inches

Image scan time — 52 sec (min)

Wavelength scan time — 120 sec (min)

Laser wavelengths — 325 nm, 442 nm, 488 nm, 514 nm and 633 nm

Detection wavelength range — 200 nm - 2000 nm

Detectable fluorescent power — 3×10^{-12} watts/bit

Detector bandwidth 50 Hz — 3.1 kHz

Image resolution — 2-line pairs/mm

Magnification — variable to 6x.

FBI LABORATORY DIVISIONS NATIONAL STOLEN ART FILE

C. Thomas Spitzer

FBI Laboratory
Washington, D.C.

During the past decade, theft of valuable works of art has increased at an alarming rate. It is estimated that the value of stolen art recovered throughout the world exceeds \$1 billion annually, with thefts in the United States accounting for more than \$50 million of the total amount (Mason 1979).

There are many reasons for the increase in art thefts. Because of the attractive nature of art as an investment, objects are sought after by criminals from all parts of the world. Unfortunately, because many museums, galleries and homes lack adequate security, artwork can be easy prey for art thieves. A major factor in the growth of stolen art is the difficulty in identifying suspicious objects. Works of fine art generally do not contain identifying numbers or names of lawful owners, and owners often do not have sufficient identifying data to authenticate their works when recovered by the police.

In the past, law enforcement agencies did not have a central file with information on stolen and recovered art objects. Frequently, such information was not passed on to other law enforcement agencies. This allowed art thieves to operate freely in areas distant from the original theft.

HISTORY

In response to the problems of art theft and as an effort to assist law enforcement agencies, the FBI Laboratory in 1979 established a computerized data file to collect information concerning stolen and recovered works of art.

The art file was designed to contain descriptive information and photographic reproductions of stolen and recovered art objects. Reported stolen art items are searched in the file and placed on record. If an object is associated with an item in file, both the agency making the inquiry and the agency submitting the initial theft report are contacted and provided with the information. The FBI Laboratory does not attempt to authenticate the items in question. This function is best performed by art experts who are qualified and willing to testify in court concerning their findings.

FUNCTION

The National Stolen Art File uses a computer interfaced with a computer-driven Panasonic Optical Memory Disc Recorder for viewing items. The computer program is designed to contain descriptive data

and, when submitted, photographs of stolen and recovered art objects.

Information received from law enforcement agencies is coded in the laboratory for entry into the computer's database according to descriptive elements including dimensions, composition, subject matter, principal color and other related matters.

Searches are made in the art file in an effort to associate recovered items with previously entered stolen objects. When an association is made, the agency submitting the data to the art file is contacted and provided with the name of the agency that sent the theft report to the laboratory. Items are often authenticated by local art experts who are willing to testify to their opinions about the identity of the art objects in question.

Submitting Data to the Art File

Art objects sent to the FBI Laboratory for searching and inclusion in the art file must be the subject of a criminal investigation and valued at \$2,000 or more. Information should be entered on an FBI form FD-531 (Figure 1), which is available from FBI Field Offices throughout the United States. This form, accompanied with a photograph of the object, should be sent to the following address:

Federal Bureau of Investigation
9th and Pennsylvania Avenue, N.W.
Washington, D.C. 20535

Attention: Laboratory Division-Document Section

Photographs submitted to the laboratory will be retained in the records of the art file.

When art objects are recovered or are no longer being sought, the laboratory must be notified so that data can be removed from file.

Stolen Paintings Recovered

Recently, agents of the FBI's San Francisco Division received information from a confidential source about three stolen paintings of American artist Frederic Remington. Because of the limited description, it was extremely difficult to determine the source of the theft. Investigators telephoned the laboratory for assistance. As a result of a search of the National Stolen Art File, an entry was located that matched the description of the suspect items. Each FBI Office was notified of the possible association of the paintings with a theft report. It was later determined that the paintings observed in California were identical to the paintings previously reported stolen to the Laboratory.

STOLEN ART DATA SHEET

☐ A. STOLEN or ☐ B. RECOVERED

FIELD OFFICE: _____

FILE NUMBER: _____

(Check appropriate data)

DATE: _____

1. PAINTING

- ☐ (a) OIL
☐ (b) WATERCOLOR
☐ (c) GOUCHE
☐ (d) TEMPERA
☐ (e) ACRYLIC
☐ (f) COLLAGE
☐ (g) MONTAGE
☐ (h) MIXED MEDIUM
☐ (i) OTHER (describe)

2. DRAWING

- ☐ (a) PEN & INK
☐ (b) CRAYON
☐ (c) PENCIL
☐ (d) PASTEL
☐ (e) CHARCOAL
☐ (f) COLLAGE
☐ (g) MIXED
☐ (h) OTHER (describe)

3. PRINT

- ☐ (a) ETCHING
☐ (b) ENGRAVING
☐ (c) LITHOGRAPH
☐ (d) LINOCUT
☐ (e) SILKSCREEN
☐ (f) BATIK
☐ (g) WOODCUT
☐ (h) AQUATINT
☐ (i) OTHER (describe)

4. GROUND

- ☐ (a) CANVAS
☐ (b) COMPOSITION
☐ (c) PAPER
☐ (d) WOOD
☐ (e) OTHER (describe)

5. SCULPTURE

- ☐ (a) BRONZE
☐ (b) WOOD
☐ (c) MARBLE
☐ (d) STONE
☐ (e) STEEL
☐ (f) FIBERGLASS
☐ (g) CLAY
☐ (h) PLASTER
☐ (i) MIXED
☐ (j) OTHER (describe)

6. PHOTOGRAPHY

- ☐ (a) BLACK & WHITE
☐ (b) COLOR
☐ (c) SEPIA
☐ (d) TINT

7. FINISH (photograph)

- ☐ (a) MATTE
☐ (b) GLOSSY

8. SUBJECT OF WORK

- ☐ (a) LANDSCAPE
☐ (b) SEASCAPE
☐ (c) CITYSCAPE
☐ (d) INTERIOR
☐ (e) PORTRAIT
☐ (f) FIGURE STUDY
☐ (g) RELIGIOUS
☐ (h) STILL LIFE
☐ (i) ABSTRACT
☐ (j) ANIMAL
☐ (k) OTHER (describe)

9. FABRICATION (sculpture)

- ☐ (a) CARVED
☐ (b) CASTING
☐ (c) WELDED
☐ (d) OTHER (describe)

11. SCHOOL OF ART

- ☐ (a) REALISM
☐ (b) EXPRESSIONISM
☐ (c) IMPRESSIONISM
☐ (d) ABSTRACT
☐ (e) SURREALISM
☐ (f) OTHER (describe)

10. OTHER

- ☐ (a) TAPESTRY
☐ (b) GLASS
☐ (c) STAINED GLASS
☐ (d) MOSAIC
☐ (e) CARVED IVORY
☐ (f) OTHER (describe)

ARTIST: _____

TITLE: _____

COUNTRY: _____

IS WORK SIGNED ☐ YES ☐ NO

DIMENSIONS: _____

DOMINANT COLOR OF WORK: _____

APPROXIMATE VALUE OF WORK: _____

DESCRIPTION OF WORK: _____

TITLE OF WORK: _____

DATE OF WORK: _____ WEIGHT: _____

* USE REVERSE SIDE FOR ADDITIONAL REMARKS

FBI/DOJ

Figure 1. Stolen art data sheet.

The laboratory, through the National Stolen Art File, provided crucial information leading to the successful resolution of an art theft with a recovery value of approximately \$250,000.

Intelligence Source

The National Stolen Art File also provides information of intelligence value to law enforcement agencies concerning artists, works of art and other related matters.

Suspicious art items offered to undercover agents can be checked against the art file to determine if the items have been reported stolen. In addition, information concerning the style, medium and other known traits of a particular artist can often be determined and provided to the investigator as needed.

SUMMARY

The FBI Laboratory's National Stolen Art File is available to all duly constituted law enforcement agencies as a resource in locating stolen art objects or determining the source of recovered art items. Information describing stolen or recovered objects valued at \$2,000 or more is suitable for entry into the art file. The FBI Laboratory does not authenticate suspect works of art.

REFERENCE

Mason, D. L. (1979). Art thefts investigation, FBI Law Enforcement Bulletin, January, pp. 14-18.

DISCUSSION

Prouty: How does local law enforcement access this file? Through the local FBI office?

Spitzer: First, let me point out that we are interested in art objects that are valued at \$2,000 or more. We chose that figure as a dividing line between the people who collect a little art as a hobby and serious art collectors. Now \$2,000 would not seem to be a great deal

of money, but not many people have a piece of art costing as much as \$2,000, and if they do, the art probably has greater potential value.

Second, let me point out that we do not want to hear from prospective purchasers who just want us to "run this through the FBI's file to see if it is clear before I buy it."

Having said all that, though, I want to encourage local law enforcement officials to write to us on their letterhead, without necessarily going through the FBI office, to let us know when they are working on a criminal matter that is being investigated with the intent of prosecution.

If the criminal matter involves information about the stolen work of art, we will provide you with the forms we use to record the information. Or, if you are near one of our field offices, you can ask for those forms to use to log the material yourself.

Every 6 months we go through our files and ask the people who have corresponded with us to check the listing they sent us to be sure that all the items are still missing. In other words, we say, "Here is the list you sent us, so you do not have to go back and dig through your records. Are all these items still being sought?" If you have administratively closed on an item, draw a line through it. Send the list back to us and we will adjust our records.

Riker: Is it primarily price that determines whether your missing object is art? I mean, where do you draw the line as to art?

Spitzer: Actually, we are pretty flexible when it comes to this subject. If it is an item of property, we are eager to help you with it. We drew the line at \$2,000 only to keep our files from getting clogged with a lot of material that is not intrinsically valuable. If you had an object—perhaps a bronze statue—worth \$1,500, but you felt that it had higher potential value and you were really working on the case, we would add it to our list rather than say it does not pass the price test.

Question: Are you restricting your art to actual painting or hand work, or do you include something like photography?

Spitzer: Photography would be included. Currently, we have such things as oil paintings, drawings, tapestries, and statues. In the future we plan to get into such items as rare stamps, rare books and antiques.

BLANK PAGE

SECTION II
EXTENDED ABSTRACTS

BLANK PAGE

DIFFERENTIATION OF INKS THROUGH LASER TECHNOLOGY

M. P. Gryzik and M. Black

Orange County Sheriff-Coroner Department
Santa Ana, California

In the past, the differentiation of inks was usually accomplished by performing various nondestructive and destructive tests such as infrared, ultraviolet and thin layer chromatography. With the introduction of the laser (Light Amplification through Stimulated Emission of Radiation), an additional nondestructive test is available—a test that is rather simple to perform, involves little time and produces instantaneous results.

The Spectra-Physics Model 2020 argon-ion laser in use at this laboratory has a nominal power output of 5 watts. The beam of the laser is directed through a fiberoptic bundle (wand) enabling the light to be passed over the entire item being examined. To view the results, two filtering devices were used—the Laser-Gard goggles and the YA2 orange filter. Primarily used for developing and enhancing latent fingerprints on objects that normally could not be developed by conventional means, the laser is increasingly being employed in document-related problems (for example, erasures, obliterations, alterations and ink transfers).

For the purpose of this study, 15 manufacturer/brand name black and 15 manufacturer/brand name blue inks and eight manufacturer/brand name red inks (Table 1) were tested with the laser. The papers on which the inks were sampled included safety paper for checks, scratch pad paper and department-issue letterhead paper with a 25% rag content.

In viewing the black inks with the laser through the filters, it was found that the Pentel Rolling Ball black ink sample luminesced with a greenish cast and the Bic Biro black ink sample luminesced with a purplish cast. The remaining black ink samples displayed no observable luminescence. Of the red ink samples, the Pentel Stinger and the Pilot Razor Point luminesced with an orange cast. The remaining red inks had no observable luminescence. Finally, in the blue ink samples, the Wearever luminesced with a reddish cast. The remaining blue ink samples displayed no noticeable differentiation.

Table 1. MANUFACTURER/BRAND NAMES OF INKS

<u>BLACK INKS</u>	<u>BLUE INKS</u>	<u>RED INKS</u>
Bic Biro	Baronet	Bic Biro
Cross	Bic Biro	Blackfeet Indian Writing Co. —Swagger Stick
Faber-Castell	Blackfeet Indian Writing Co. —Swagger Stick	Longlife
Fisher-Repro	Cross	Papermate (fiber tip)
Longlife	Faber-Castell	Papermate
Majorline	Nadel	Pentel Stinger
National	Papermate	Pilot Razor Point
Papermate	Papermate (eraser)	Wearever
Papermate (eraser)	Parker	
Parker	Pilot Razor Point	
Pentel (SP 308)	Ritepoint	
Pentel Rolling Ball	Sheaffer	
Pilot Razor Point	Scripto (eraser)	
Universal	Universal	
Wearever	Wearever	

DISCUSSION AND OBSERVATIONS

The difficulty encountered in this experiment was not so much in observing the luminescence but in photographically recording the results on 35 mm color slide film. The following factors affected the photographic reproduction of the luminescent colors: the type of film used, the chemistry of the processing procedure and the type of barrier filter used. The Kodak Kodachrome 200 color slide film was found to be more sensitive to the observed luminescent colors than the Kodak Ektachrome 200. Photography through the Laser-Gard goggles produced better color contrast of

the luminescent colors than photography through the YA2 filters. Finally, careful handling of the documents was important because the inherent luminescent residue of the fingerprints can affect the luminescent results of the inks being tested. As a note, the various papers used had no effect on the luminescent results of the sample inks.

The increased importance of the use of the laser on certain document problems cannot be overstressed. The laser is another tool in the examiner's arsenal of scientific equipment to be used when faced with a document problem involving inks. More importantly it is nondestructive to the document.

THE EXAMINATION OF ALTERED AND COUNTERFEIT CREDIT CARDS

R. P. Johnson

Northern Virginia Regional Crime Laboratory
Bureau of Forensic Science
Merrifield, Virginia

The exploitation of altered and counterfeit credit cards has accelerated steadily with the increased use of "plastic money" in the forms of credit cards, debit cards and special (proprietary) use cards. Consequently, the examination of these illicit cards and various supporting documents and manufacturing equipment has become a relatively new area of forensic expertise for questioned document examiners. The examiner will be exposed to three general types of credit cards: the genuine credit cards containing manufacturing anomalies that make them suspect, the genuine cards that have been altered and the counterfeit credit cards.

Genuine credit cards can be altered or re-embossed with a portable embossing machine after the original name and numbers have been flattened by heat or mechanical means. Even after being re-embossed, however, the plastic card retains remnants of the original embossing, which can be made visible by applying glaring light to the back surface of the questioned card. The altered signature panels of these cards should also be carefully examined with filters and infrared luminescence photography in an attempt to recover the original owner's signature. The font style of letters and numbers used on altered cards should be compared to known standards of commercially available embossers in an effort to identify the manufacturer for the investigative agency.

Counterfeit credit cards have been produced using two divergent forms of printing, the silk-screen process and offset printing. Silk-screen counterfeit credit

cards can be identified by the characteristic serrated edges on the printed images, left by the screen used in this process. The silk-screen cards are not laminated as are genuine credit cards; therefore, if the printed image can be removed from the core stock by light scraping, the preliminary assumption can be made that the credit card in question is a silk-screen counterfeit. It should be noted that some genuine credit cards have silk-screen graphics as part of their design, for example, images printed in special metallic inks and some signature panels. These limited uses of silk-screen graphics on genuine cards should not be confused with the counterfeit cards in which all the images are printed by the silk-screen process.

Offset printing has recently been used by forgers to improve the quality of the printed images on counterfeit credit cards and to allow these cards to be laminated. However, the quality of the offset printing, the image register and the font style of the embossing all can be used to identify counterfeit credit cards from genuine ones. Offset printing has also been used to produce counterfeit drivers licenses and I.D. cards to accompany the counterfeit credit cards.

The credit card industry has been incorporating security devices, such as the hologram foils, into the manufacture of credit cards to make them more difficult to alter or counterfeit. However, the forgers' ability to mimic these security devices has been increasing in sophistication, thereby limiting the useful life of any one security device.

BLANK PAGE

-

SEQUENCE OF WRITING—PENCIL AND POROUS TIP PEN

D. R. Howes

New York State Police Crime Laboratory
Albany, New York

Research was conducted in an attempt to determine the sequence of strokes in line crossings between porous tip pens and pencils. The research used a Video Spectral Comparator to view the strokes under infrared absorption. A certain phenomenon was observed when viewing the cross-strokes of these two writing instruments in which the ink of the porous tip pen line was rendered invisible when viewed on the screen of the Video Spectral Comparator under infrared absorption. In each case where the pen stroke crossed over the pencil stroke, a visible mark appeared for a short distance on the otherwise invisible pen line just after the pen line crossed over the pencil line. In each case when the pencil stroke crossed over the pen stroke no visible mark was found on the pen line adjacent to the pencil line. These tests led to the conclusion that, since the ink of the pen is rendered invisible under infrared absorption and the pencil line remains visible, this noted visible mark on the pen line after crossing the pencil line had to be some of the graphite from the surface of the pencil stroke being picked up by the pen tip and redeposited back on the paper.

Considering effects of the time interval between pen strokes crossing pencil strokes with possible erosion of the graphite from the paper surface prior to the crossing of the pen stroke, led to further tests in which the pencil line was rubbed with a facial tissue before making the crossing pen stroke. When viewed under infrared absorption on the Video Spectral Comparator it was found that quite often no visible mark, which should be there, could be detected on the pen line adjacent to the pencil line.

Further tests were made to determine whether the visible mark that appeared on the pen line in previous tests where the pen line crossed the pencil line could also be removed by erosion. Rubbing the areas of the

strokes on these previous test crossings with a facial tissue and reviewing them on the Video Spectral Comparator resulted in these visible marks on the pen line remaining visible.

Other tests with pen lines crossing pencil lines were conducted with papers of different surface texture and with plastic tip porous pens. These tests also revealed that the visible mark that should appear on the pen line after crossing the pencil line sometimes did not appear, especially on glossier surfaced paper.

From the outcome of my research I believe that one can draw the following conclusions:

1. In any sequence-of-stroke question involving a porous tip pen and pencil, a definite opinion can be rendered that the pen stroke crossed over the pencil stroke when the ink of the pen stroke is rendered invisible under infrared absorption on the Video Spectral Comparator and a visible mark is noted on the pen line adjacent to the pencil line. Also, the direction of the pen stroke can be determined by which side of the pencil line the visible mark falls on the pen stroke.

2. Due to the factors of the time interval between strokes with possible surface erosion, the type of paper surface and plastic tip pens, no definite opinion can be rendered as to which stroke was made over the other when no visible mark is present on the pen line adjacent to the pencil line when the pen line is rendered invisible under infrared absorption on the Video Spectral Comparator.

3. When the porous tip pen picks up and redeposits the graphite from the pencil line as it crosses over the pencil line, the visible mark left on the pen line when viewed under infrared absorption on the Video Spectral Comparator does not disappear under normal wearing erosion.

BLANK PAGE

EXPERIMENTS IN BALL POINT INK AGING USING INFRARED SPECTROSCOPY

H. J. Humecki

W. C. McCrone Associates, Inc.
Chicago, Illinois

The ability to determine the sequence of ball point ink entries on documents is important in exposing fraud involving back dating. The experiments described here indicate that infrared spectroscopy has some value in comparing the ages of entries made with the same ball point ink.

Once a ball point ink has been applied to paper, its composition changes with time. It is uncertain whether this is caused by evaporation of more volatile components, oxidation, polymerization or interaction with the paper on which it is written. Evidence indicates that more than one of these factors is involved in the aging process. Infrared spectroscopy offers an opportunity to follow the aging process without presuming to know which factors are dominant.

A series of ink samples identified as formula 353 on paper were obtained for experimentation. These samples were prepared under laboratory conditions on a writeout machine and cover a period of 22 years. Samples were prepared by treating plugs of paper with a mixture of equal proportions of ethanol and pyridine and with pyridine alone. Initial tests were carried out on large inked specimens of approximately 0.25 inch. Samples as small as single plugs 1 mm in diameter have also been successfully extracted and analyzed.

The extract was transferred to a salt window for analysis. For these large samples, a 1 x 4 mm window was used with a 6 beam condenser. The instrumentation was of a Digilab Model FTS-20C equipped with a triglycine sulfate (TGS) detector. Figures 1 (a and b) are spectra of the extractables ratioed against a blank salt plate and against the paper extract, respectively. Minor differences were observed although the spectra are essentially the same. This indicates that, at least on this paper, there was no interference from the paper extractables.

Comparing the spectra of ink extractables taken over a 22-year span, it was observed that the O—H band at about 3 μm diminished with time when compared to other spectral lines. The ratio of the O—H band at 3 μm to the C—H band at 3.4 μm was plotted against

age. The results of that plot are shown as Figure 1(c). The O—H band, which probably represents some of the volatile solvents present, diminishes most rapidly in the first years and then decreases at a slower rate. The useful range appears to be somewhere between zero and 10 years for this particular ink. A similar plot was made employing the ratio of the carbonyl band at 5.8 μm to the O—H band. Unlike the O—H band, the C=O band increases with time (Figure 2). This would indicate an increase in some oxidized substance. The identity of the substance is unknown. The precision of this measurement is poorer than that for the O—H measurement, consequently it would not appear as useful for dating purposes.

High-quality spectra can be obtained from the ink extracted from individual microplugs, although the process must be modified. One and one-half to two microliters of pyridine are added to a microplug in a 0.3 ml cone-shaped reaction vial with Teflon®-faced screw cap. After 10 minutes, the extract is drawn up into a 200 μm i.d. capillary brush. The capillary brush is made by fusing several borosilicate glass fibers to the inside surface of a 200 μm x 4 inch borosilicate capillary. The fibers are trimmed to a point with scissors and the capillary rinsed with distilled pyridine.

After evaporation of the rinse solution, the open end of the capillary is dipped into the extract and as much solvent as will migrate is drawn up. The capillary brush is then inverted and the brush end touched gently and repeatedly to a salt window. This must be done while viewing under a stereo microscope at 6x to 25x. A 1 mm microdot generally provides enough ink for a spot 200 μm to 400 μm in diameter. The spots can be held to 150 μm to 200 μm diameter if necessary. The same infrared spectrophotometer with a microscope attachment, and the more sensitive mercury-cadmium telluride detector is used.

In conclusion, infrared spectroscopy has been used to follow the aging process of ball point inks on paper. The ratio of the O—H to C—H bands diminishes with time and becomes asymptotic after about 10 years.

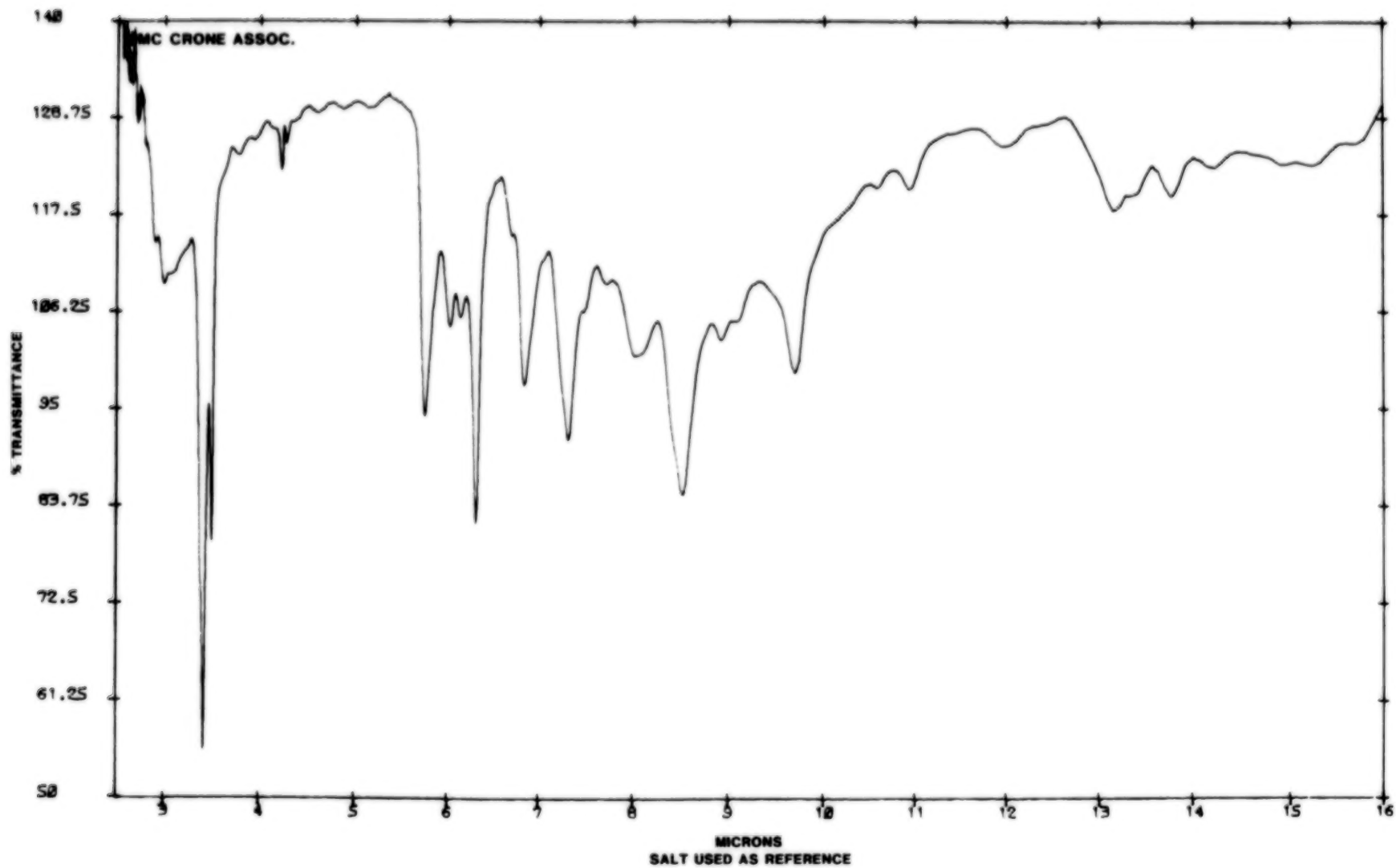
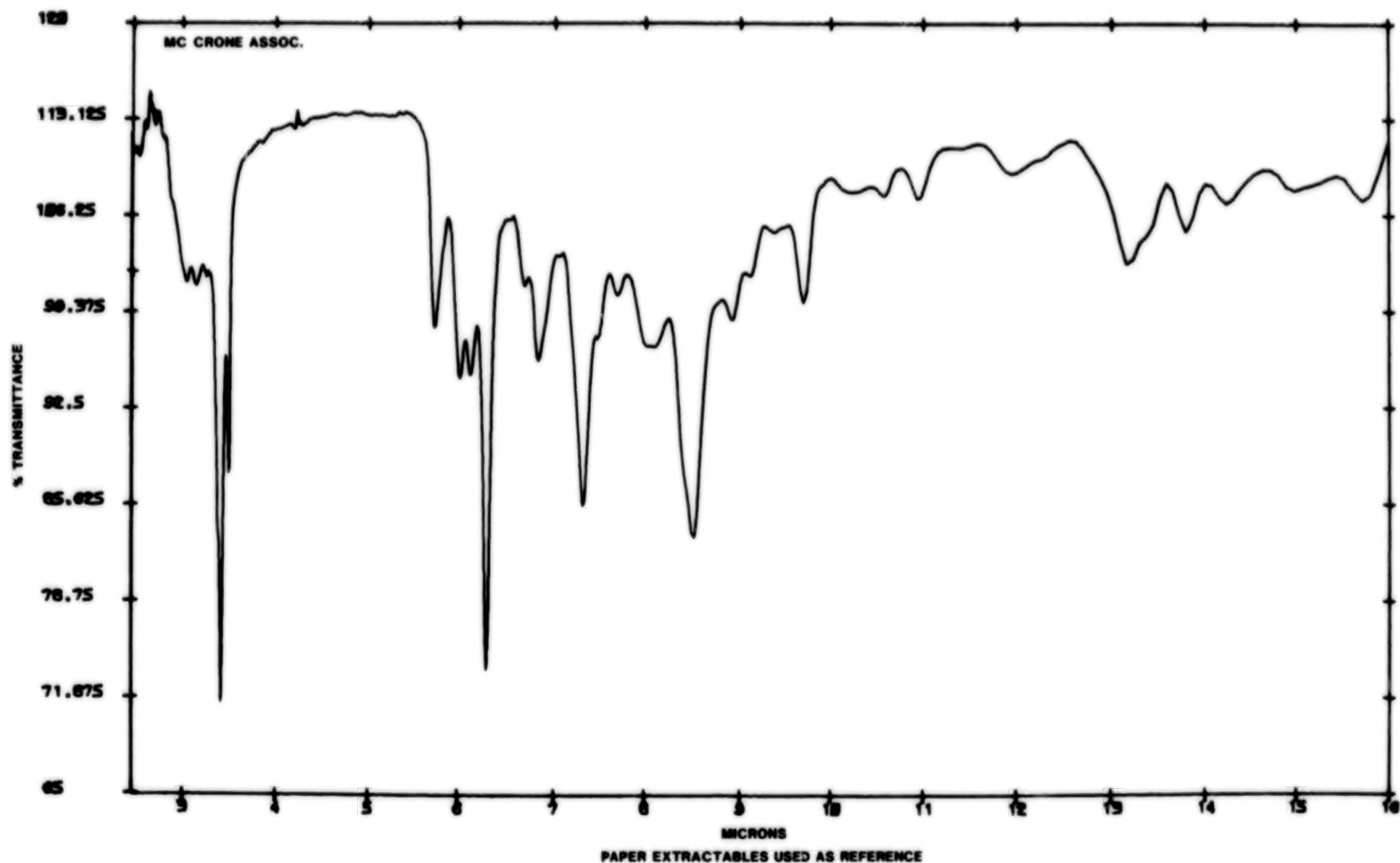
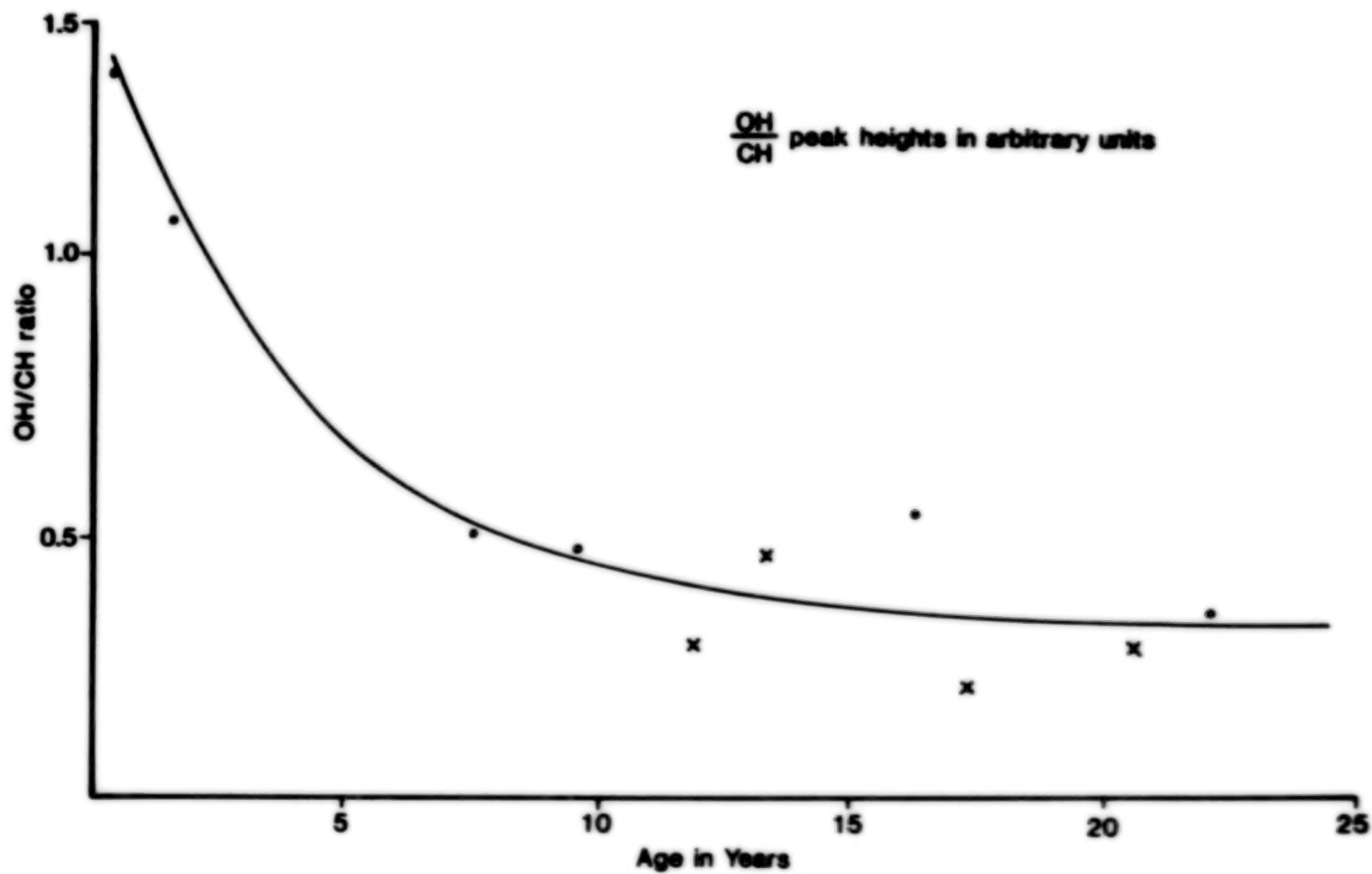


Figure 1(a). Infrared spectrum of ink extractables using salt as the reference.



(b). Infrared spectrum of ink extractables using the extractables from blank paper as a reference.



(c). Plot of the O—H versus C—H absorption versus the age in years.

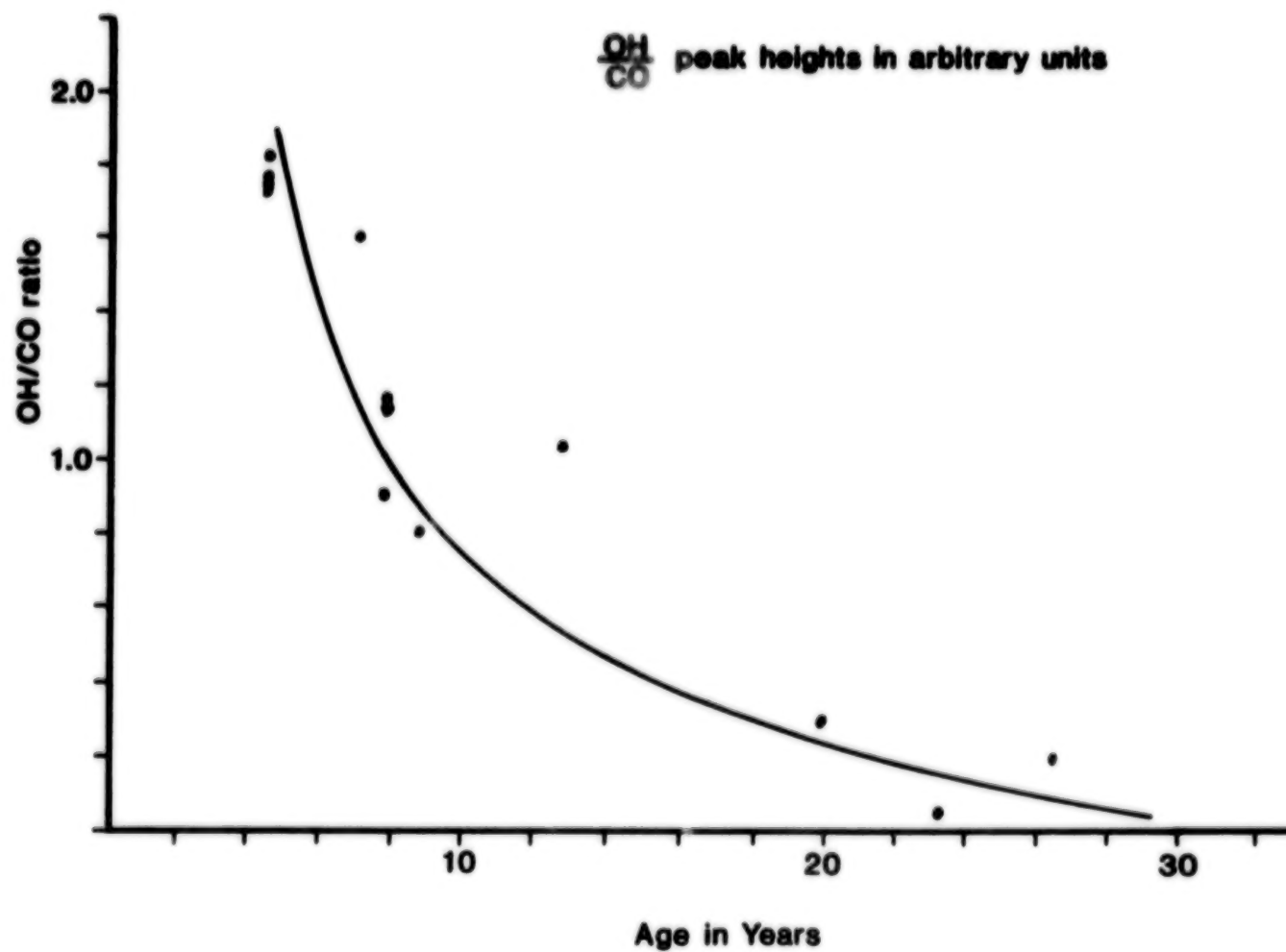


Figure 2. O—H versus C—O absorption ratios versus age in years.

BLANK PAGE

CLASSIFYING THE COMPUTER-PRINTED DOCUMENT

J. Winchester

Florida Department of Law Enforcement
Tallahassee, Florida

The purpose of this paper is to describe the classification of computer-printed documents by using a possible print technology system classification scheme. The classification by technology was conducted for the purpose of examining the computer-printed documents for visual and microscopic print quality defects associated with specific print technology.

METHOD

This procedure involves classifying the computer-printed documents into categories of impact printers or nonimpact printers. Impact printers that print fully formed characters include high-speed printers such as the drum, chain or train and band. Serial printers include the printwheel and thimble. Dot matrix impact printers include the multistylus printhead and thermal. Nonimpact printers that print fully formed characters include the electrostatic and laser technologies. Dot matrix nonimpact printers include ink jet, thermal and graphics. These are examples of some of the printer technologies on the market.

Impact and nonimpact printer technology allows characters to be placed on the paper in one of three ways, (1) one character at a time, serially, (2) an entire line at once, or (3) the entire page at once.

RESULTS

Original computer printout samples and literature describing the printer technology were cataloged. The samples of print quality and catalogs were requested from 158 computer-printer manufacturers.

The cataloged documents permitted a visual and microscopic examination of the various printer technologies. The visual characteristics included the dimension of the paper accepted by the printer, the type of paper used and the type of ribbon or ink used. For example, "journal printers" use narrow paper, limiting the number of print columns. Some print technologies require specially coated paper, as contrasted with the printers in which plain paper, either roll or sheet, can be used. At one time, carbon ribbon was used in one dot matrix printer.

The dot matrix formations of both impact and non-impact printers could be grouped by the appearance of the dot matrix formation on the page. One printer used a square dot matrix printhead; others used round dot matrix printheads. Other characteristics pertaining to the samples cataloged are noted and illustrated during the discussion.

Thus, based on the use of a print technology system classification scheme, visual and microscopic analysis of characteristics of the ribbon, the paper and print quality defects of the character formation, preliminary conclusions may be made by the document examiner in the examination of hard-copy computer printouts.

BLANK PAGE

PRELIMINARY EXAMINATION OF MACHINE COPIER TONERS BY INFRARED SPECTROPHOTOMETRY AND PYROLYSIS/GAS CHROMATOGRAPHY

J. Zimmerman and M. J. Kimmett

Aurora Police Department
Aurora, Colorado

D. Mooney

Colorado Bureau of Investigation
Denver, Colorado

The purpose of this project is twofold:

1. To determine if dry toners from indirect process copy machines could be analyzed by infrared spectrophotometry, and each one differentiated from all others, and

2. To determine if the toner could be extracted from a copied document and run on the infrared spectrophotometer, and if it would be consistent with the spectra of raw toner powders from the same copy machine.

If there is a consistency between toner powder and toner extracted from a copied document, then raw toners could be collected from various companies, a spectra developed and a library established. An unknown machine copy might be matched for class characteristics by extracting the toner from the paper and performing a library search for peak match and/or functional groups. Where similarities were found, the individual spectra then could be compared by hand to the questioned document spectra to determine if a match could be made.

Thirty-five different toners from five companies were collected from manufacturers and analyzed. Eighteen different groups of similar spectra were established, of which seven consisted of more than one toner. One group consisted of eight different toners from three manufacturers.

The next step in our research was to find a process to further differentiate the toners. Pyrolysis/gas chromatography so far has provided that solution. The pyrolysis/gas chromatograms of the eight toners in one

group were all differentiated from each other. The two groups chosen for this presentation demonstrate the difference in toners from the same manufacturer, and the more pronounced difference between different manufacturers:

Group 8: Minolta MT 8915-042, MT EP450 EP4502 and EP510

Group 12: Minolta EP650Z MT, Sharp 90T and 851.

So far, the toners analyzed by this process have shown differences in chromatograms for each toner. More sophisticated methods of analysis can be performed if the current method proves in some cases to lack sufficient specificity.

The application of this research is seen in receiving a machine copy as a questioned document with no standards for comparison. Infrared spectrophotometer analysis can be run of a small sample for a library search to narrow down the possible source of the toner. Then pyrolysis/gas chromatography can be performed, and the individual spectra match made to find the toner used. Initially the search would be for the copy machine using a particular type of toner. If suspect machines are located, the actual machine could be found by attempting a match through trash marks, or drum or lens defects. When a machine copy is received as a questioned document, along with products of suspect sources of machines, pyrolysis/gas chromatography could be performed for each document to match or eliminate the questioned document from the standards.

BLANK PAGE

PYROLYSIS GC/MS OF INKS AND PAPER IN DOCUMENT IDENTIFICATION

E. J. Levy and T. P. Wampler

Chemical Data Systems

Oxford, Pennsylvania

The use of pyrolysis in the forensic laboratory for the analysis of solid samples by gas chromatography (GC) and gas chromatography mass spectrometry (GC/MS) has frequently been limited to the examination of paint samples, as by Stewart (1974) and May *et al.* (1973), although other samples (fibers, hairs, tapes, blood) have been studied and Wheals (1980) has prepared an overview of the techniques used. Other analysts (Schfizadeh *et al.* 1979; Franklin 1978) have studied the pyrolysis of cellulose. The objective of this examination was to pyrolyze polymeric toner systems applied to paper in the production of photocopies.

EXPERIMENTAL

Photocopies from a variety of commercial copying machines (Table 1) were examined by pyrolyzing small samples of the paper with and without toner, and comparing the pyrograms. For basic differentiations, a 1 mm x 1 mm piece of paper with toner was pyrolyzed at 650°C for 10 sec using a Chemical Data Systems Model 120 Pyroprobe. Closely related copies required the analysis of a 1 mm x 5 mm strip for the examination of minor peaks. Chromatography was carried out using a 50 m x 0.25 mm fused silica SE54 capillary col-

Table 1. OCCURRENCE OF PEAKS IN PYROGRAMS OF PHOTOCOPIER TONERS AT 650°C FOR 10 SECONDS

	PEAK RETENTION TIME IN MINUTES																			
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Photocopier Brand	11.3	12.8	13.2	13.4	13.8	14.0	15.1	15.6	16.1	16.7	17.8	19.2	19.3	20.5	20.8	24.7	25.2	27.0	35.7	38.8
Kodak																				
100	X	X		X			X	X		X	X		X	X		X		X		
150	X	X		X			X	X		X	X		X	X		X		X		
Minolta																				
EP530		X					X	X	X	X	X	X	X	X		X				
Savin																				
770	X		X	X	X	X	X		X		X		X	X		X			X	X
780	X		X	X	X	X	X		X		X		X	X		X			X	X
Xerox																				
1035		X					X	X		X	X	X	X	X		X				
1045		X					X	X		X	X	X	X	X		X				
2830		X					X	X		X	X	X	X	X		X				
3300							X				X			X		X				
8200							X			X	X	X	X	X		X				
Mita																				
DC 133R	X		X				X	X	X	X	X		X	X		X	X			
Panasonic																				
FP1801	X		X				X	X		X	X		X	X	X	X	X			
Sharp																				
SF825	X		X				X	X		X	X	X	X	X		X	X			

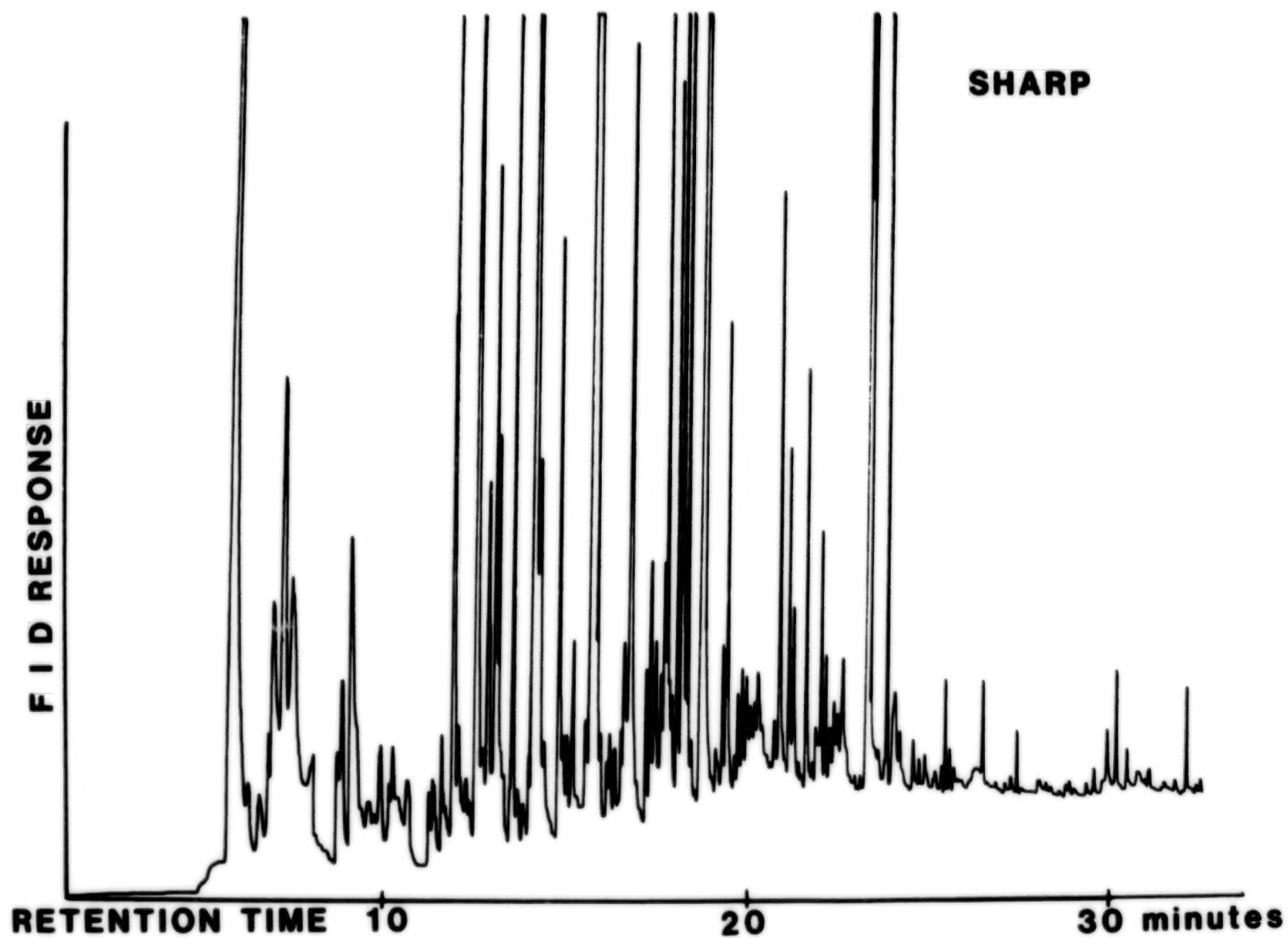


Figure 1. Pyrogram of 1 mm x 1 mm piece of Sharp brand photocopier paper with toner material, pyrolyzed at 650°C for 10 sec.

umn programmed from 25°C to 290°C at 6°/min; the carrier gas was helium at a 60:1 split ratio, and a flame ionization detector was used.

RESULTS

Pyrolysis of 12 types (6 brands) of photocopier resulted in the selection of 20 peaks for the differentiation of the samples from each other. These peaks are listed as A through T on Table 1, which shows the presence or absence of each peak for each photocopy studied. Some peaks are unique to a specific photocopier, for example, only Panasonic contains peak O and only Savin shows peaks S and T. Other brands are distinguished by a combination of common peaks. No difference was seen between the two Savin models, or three of the five Xerox models examined. Sharp, Mita and Panasonic were very similar when a 1 mm x 1 mm square was used, all looking like the pyrograms of Sharp shown in Figure 1. Pyrolyses of 1 mm x 5 mm strips, however, revealed that only Sharp contained peak L and only Panasonic showed peak O.

GCMS indicates that peak A is methyl methacrylate, B is toluene, G is furfural, J is styrene, L is butyl methacrylate and R is ethyl hexyl methacrylate. Other peaks have been tentatively identified as 1-octanol and hydroquinone.

CONCLUSIONS

Pyrolysis GCMS offers a sensitive and relatively straightforward means of distinguishing photocopier types from each other, based on the polymer toner systems used in the photocopying process. Variations from paper to paper suggest that the technique could be extended to the identification of other documents, as well as the examination of other inking systems.

REFERENCES

- Franklin, W. (1978). Direct pyrolysis of cellulose and cellulose deriv. in an M.S. with data systems, *Anal. Chem.*, 50:992.
- May, R., Pearson, E., Porter, J. and Scothern, M. (1973). A reproducible pyrolysis gas chromatographic system for the analysis of paints and plastics, *The Analyst*, 98:364.
- Schfzadeh, F., Furneaux, R., Cochran, T., Scholl, J. and Sakai, Y. (1979). Production of levoglucosan and glucose from cellulose material, *J. Appl. Polym. Sci.*, 23:3525.
- Stewart, W. (1974). Pyrolysis gas chromatographic analysis of automobile paints, *J. Forensic Sci.*, 19:121.
- Wheals, B. (1980-1981). Analytical pyrolysis techniques in forensic science, *J.A.A.P.*, 2:277.

BLANK PAGE

METHODS CONCERNING CLASSIFICATION AND IDENTIFICATION OF PHOTOCOPIES

H. G. Heuser

Bundeskriminalamt

Wiesbaden, Federal Republic of Germany

Determining the make and model of photocopy machines where only copies are available has become an essential task in casework concerning terrorism and serious crime. This is especially important when letters, connected with bombings or assassinations where the perpetrators take credit for the offense, exist only as copies. In order to trace the perpetrator, it is important to identify the tools used.

Methods to differentiate between the various models of photocopy machines are oriented by the processes of electrophotographic imaging (Corbobbese *et al.* 1985; Heuser 1984; Holland 1984; Totty and Baxendale 1981). These methods can be divided into two groups:

1. Pictorial magnification by means of optical instruments including the scanning electron microscope (SEM) for discrimination between the main processes and measurements of physical properties related to image transfer.

2. Analytical methods determining the physical and chemical properties of the toners.

Basic operating principles of a particular copying machine can be characterized by the visual information provided by the SEM. Table 1(a) shows the stages of the electrophotographic process including the various techniques applied. Table 1(b) lists the analytical approaches to examining photocopies. Figures 1 through 5 show the morphology of toner deposits relating to different operating methods. It is clearly seen that the different techniques can be easily identified. Care must be taken not to arrive at erroneous identifications based on different toner deposits as seen in the SEM, because this may be caused merely by varying settings or conditions of machines operating on the same principle. Where the similar appearance of samples allows no further discrimination, additional analytical methods as described below are of interest.

Table 1(a). STAGES OF ELECTROPHOTOGRAPHIC IMAGE FORMATION INCLUDING DIFFERENT TYPES OF PROCESSES.

MAIN GROUPS	Direct (Paper with photoconducting layer)		Indirect (Photoconductor as part of the machine)	
LATENT IMAGE	Spectral sensitizing Gradation			
DEVELOPING	Dry Toner		Liquid Toner	
	Magnetic brush Mono component Dual component		Cascade Aerosol (Obsolete)	
FUSING	Heat Pressure Heat/Pressure combined			

Measuring the characteristic curve of gray-scale reproduction by means of a densitometer provides information about gradation of the electrophotographic image and the maximum density, while producing a copy of a so-called Lagorio Table yields the spectral sensitizing of the photoconductor. Unfortunately, although these methods are very powerful in recognizing different systems, the knowledge of these parameters makes sense only when originals are available. In practical work, this is rarely the case. Nevertheless, comparing the maximum densities is of higher value, since this parameter is accessible from the copy and, more importantly, is independent over a wide range of the exposure setting. The principle of comparison is based on the fact that the maximum density in copies that a given machine can achieve is limited by its particular design. Figures 6 and 7 show characteristic curves of two models differing in contrast and maximum density.

Considering the second group of analytical methods, the SEM, mentioned before for visual examination, provides additional analytical information by means of X-ray spectroscopy. Energy dispersive X-ray analysis has proven to be very useful in recognizing monocomponent toners because these toners contain a core of magnetite (Fe) in order to operate with the magnetic brush. Dual-component toners, however, consist of mixed developer and toner where the magnetic developer acts as a carrier and is not present in the copy. Figures 8 through 11 show spectra of monocomponent versus dual-component toners and spectra of the paper as obtained using a KEVEX EDS. The high Fe peaks indicate the monocomponent toner. Interpretation of

additional inorganic components must be done with care, because paper background must be taken into account, as seen when comparing Figures 10 and 11.

Infrared spectroscopy has become an established method in forensic laboratories (Kemp and Totty 1983; Williams 1983). Horacek and Muller (1985) have developed a new preparation technique that is extremely easy to apply.

In our laboratory, experiments have recently been done on bulk toners using the Differential Scanning Calorimetry (DSC). Toners have to be tuned by the manufacturer to the specific requirements of the machine's operating principle, for example, the heat applied for fixing. Therefore, thermal analysis may be useful. Since, in most cases, melting points cannot be identified at precise temperatures in the hot-stage microscope, DSC allows determination of points of phase transformation, segregation and oxidation over a wide temperature range. Figures 12 and 13 show two types of monocomponent toners from one manufacturer. The differences in melting points and exothermic reactions are clearly seen. These preliminary results should be reproducible when switching over to samples prepared from a copy. The small amounts of material may cause difficulties. It should also be considered that the method is extremely time-consuming.

Some experimental approaches to the identification of photocopies have been discussed. All methods provide useful information but no one method alone is capable of positively identifying a given system. The onerous application of several methods with different capabilities is necessary.

Table 1(b). ANALYTICAL APPROACHES TO THE EXAMINATION OF PHOTOCOPIES.

Visual inspection
Scanning electron microscopy
Characteristic curve
Determining of maximum density
Measuring of spectral response
X-ray analysis
Infrared spectroscopy
Differential scanning calorimetry



Figure 1. Surface morphology of toner deposits as seen in the SEM—A.B. Dick 695, direct (coated paper), dry toner, pressure fusing.



Figure 2. Surface morphology of toner deposits as seen in the SEM—Kalle infotec 1901, indirect (PPC), liquid toner.



Figure 3. Surface morphology of toner deposits as seen in the SEM—Océ 1700, indirect (PPC), dry toner, heat fusing.

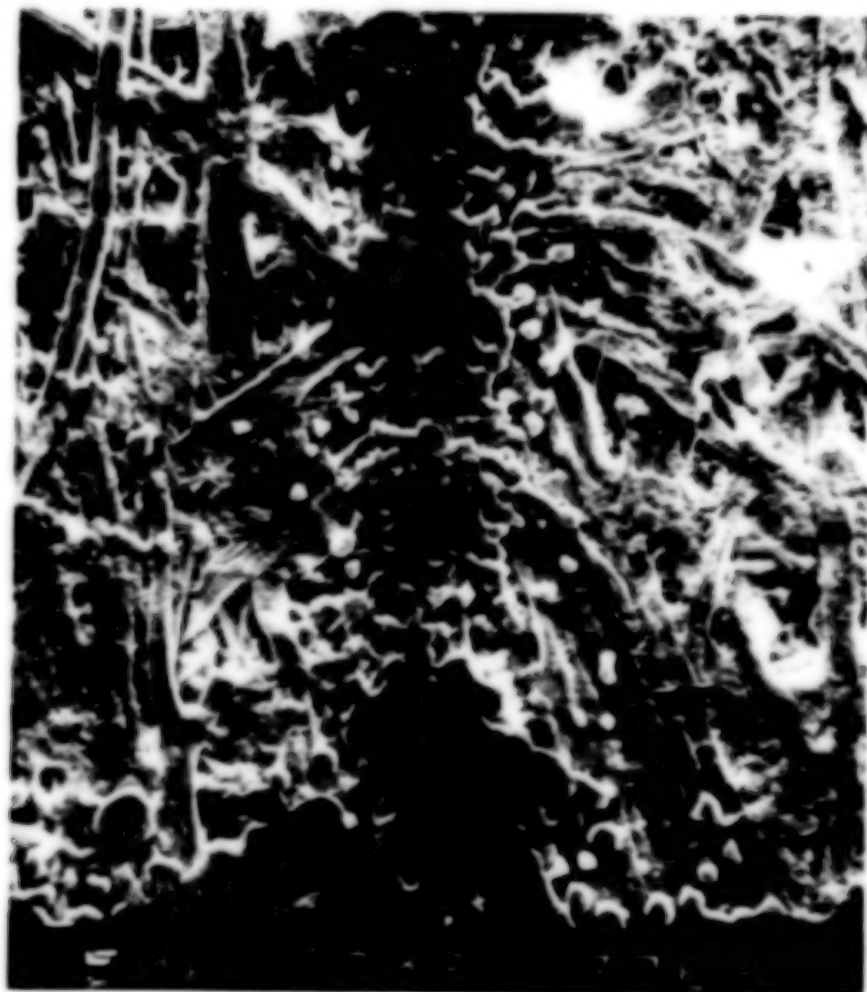


Figure 4. Surface morphology of toner deposits as seen in the SEM—Minolta/CPF Planet A3, indirect (PPC), dry toner.

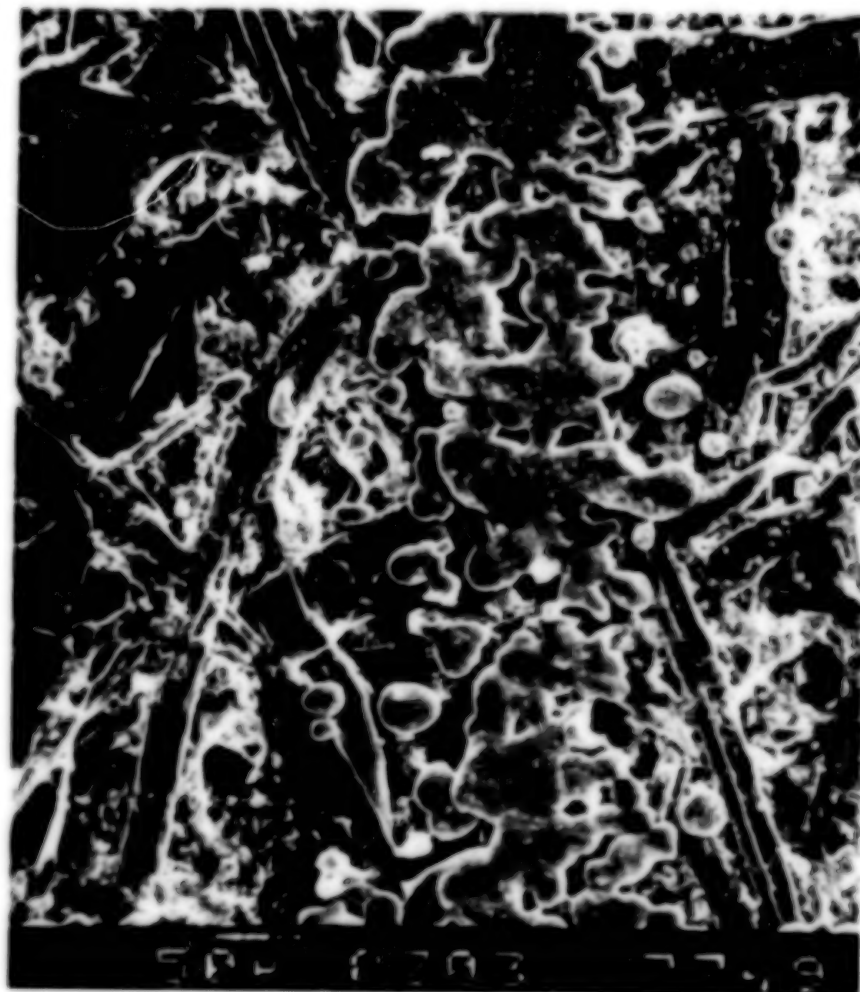


Figure 5. Surface morphology of toner deposits as seen in the SEM—Océ 1900, indirect (PPC), dry toner, combined fusing.

Figure 6. Characteristic curve.
Medium contrast.
Max. density 1.4.

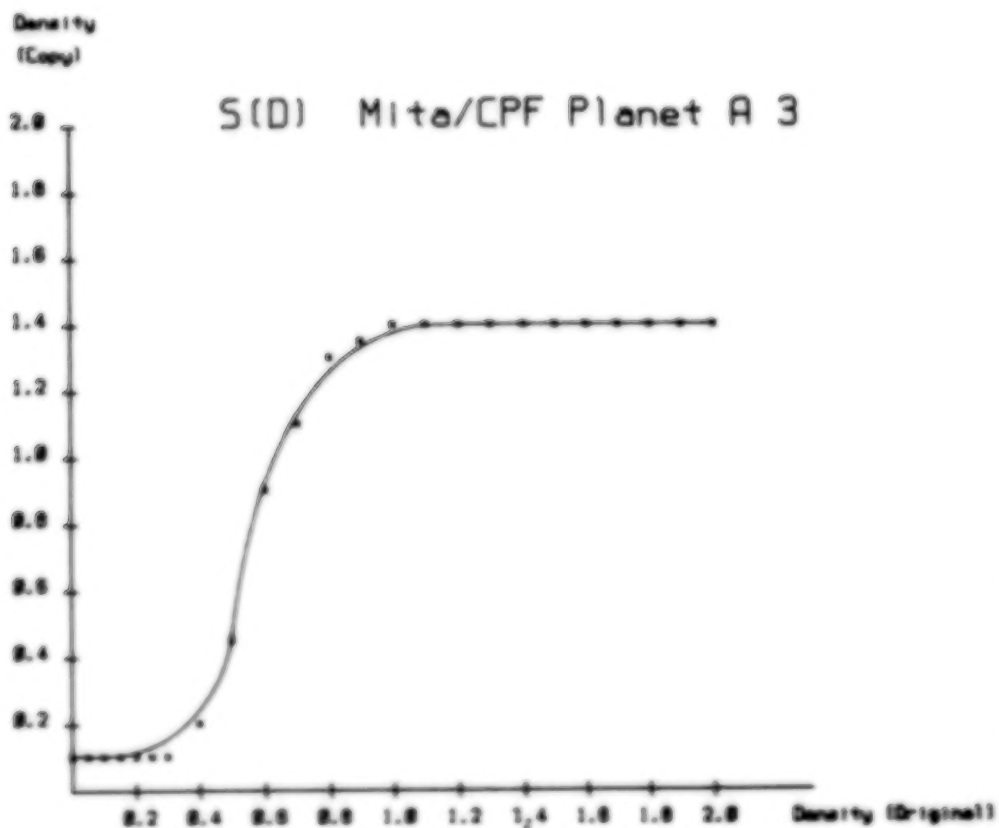
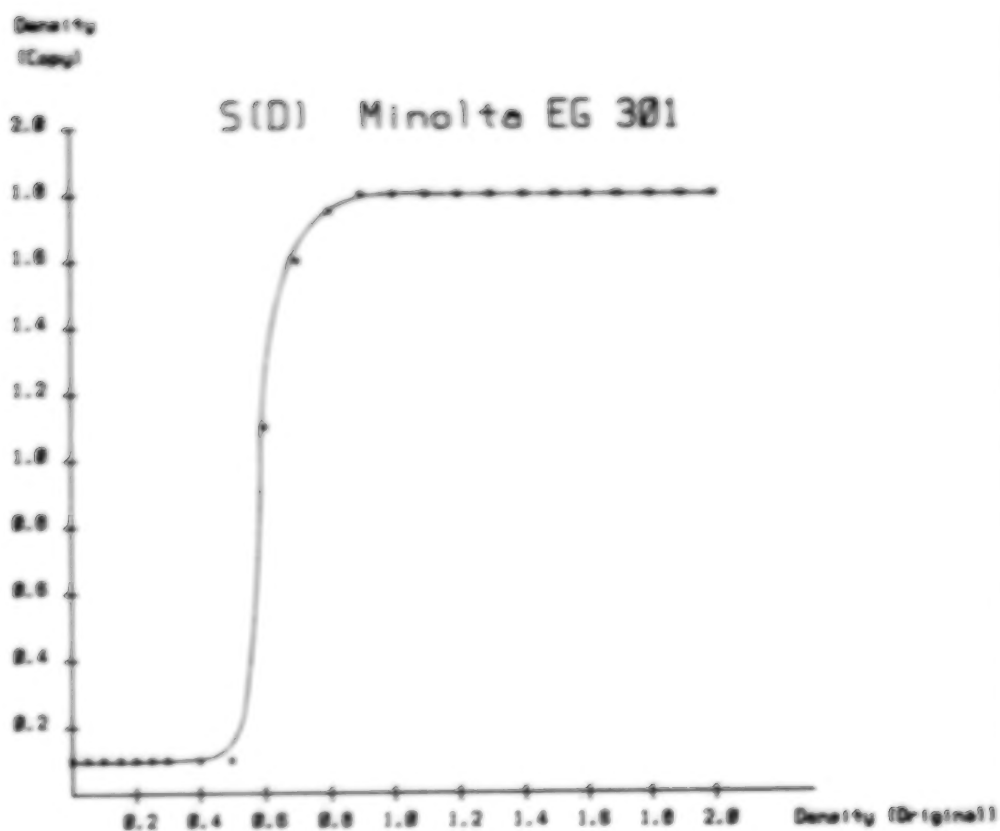


Figure 7. Characteristic curve.
High contrast.
Max. density 1.8.



22-Oct-1984 10:11:44

Execution time = 162 seconds

0627.SP

Agfa X-41

Preset = 60 secs

Vert = 2000 counts Disp = 1 Comp = 3 Elapsed = 60 secs

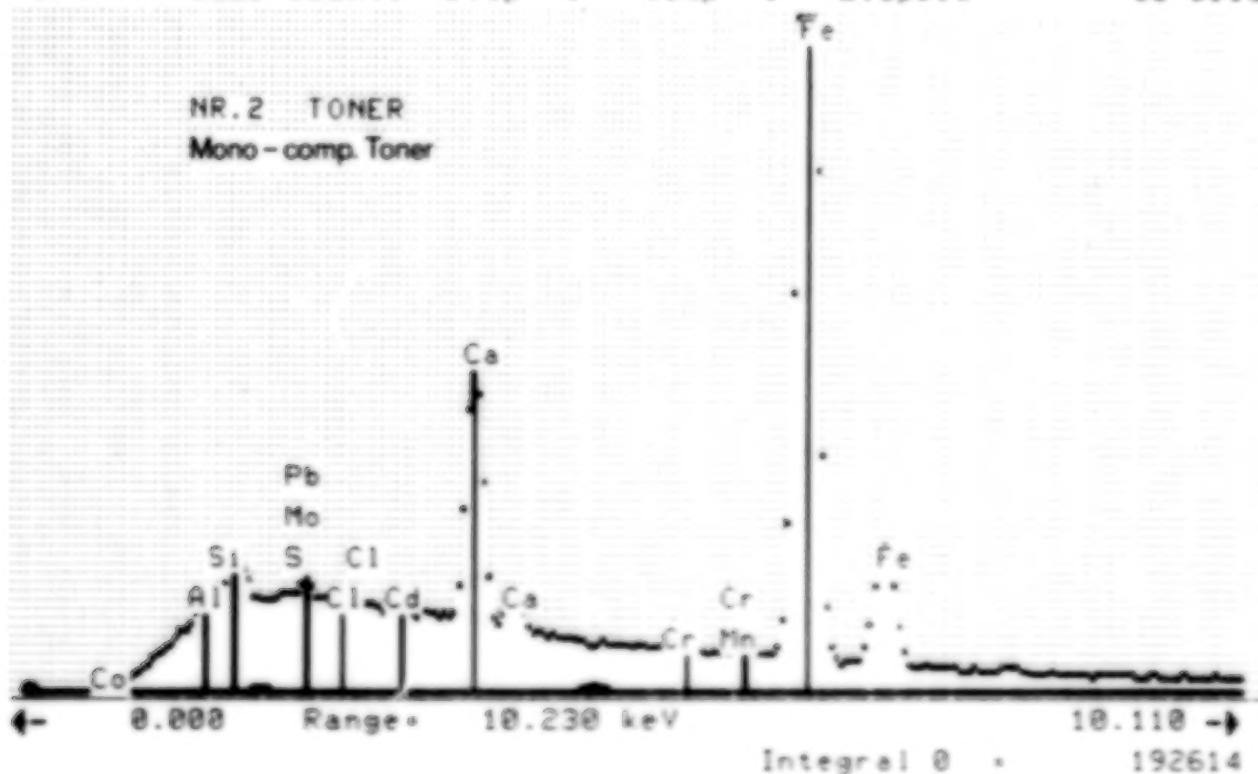


Figure 8. EDS X-ray spectrum of monocomponent toner. High Fe peak.

22-Oct-1984 10:01:06

Execution time = 171 seconds

0626.SP

Vert = 2000 counts

Disp = 1

Comp = 3

Agfa X-41

Preset =

60 secs

Elapsed =

60 secs

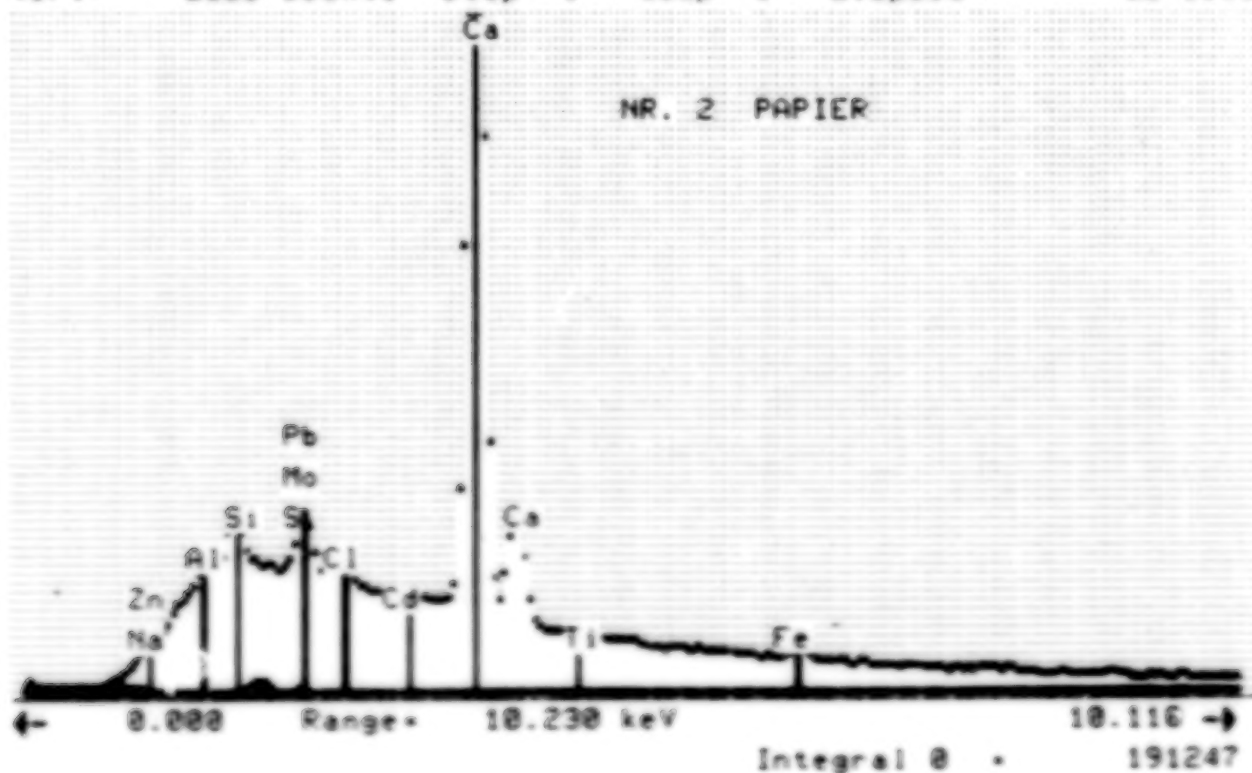


Figure 9. EDS X-ray spectrum. Same as Figure 8. Paper background.

26-Nov-1984 14:15:23

Execution time = 112 seconds

0697.SP

Vert = 5000 counts Disp = 1 Comp = 3

Rank Xerox 1045

Preset = 60 secs

Elapsed = 60 secs

NR. 28 TONER

Dual-comp. Toner

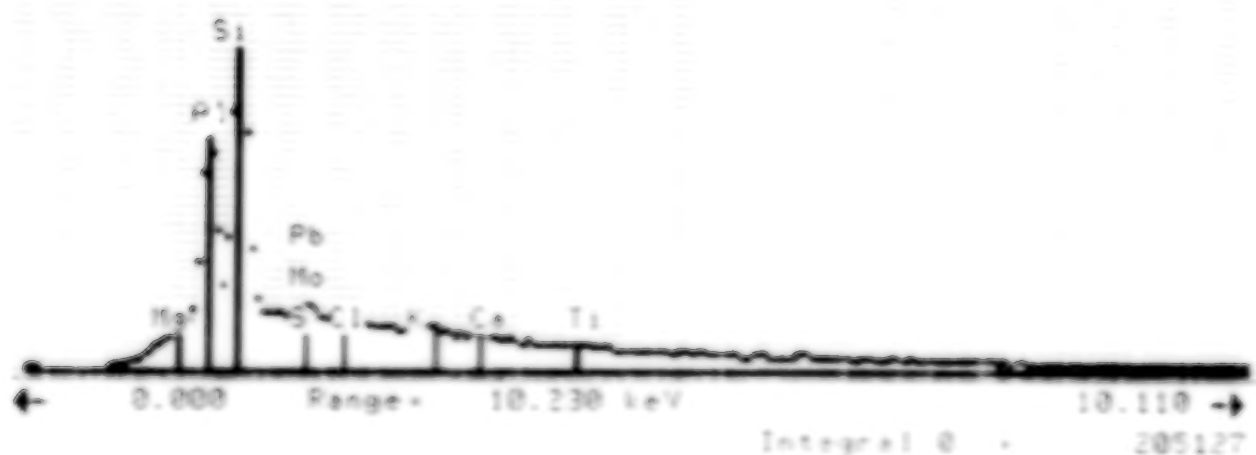


Figure 10. EDS X-ray spectrum of dual-component toner No. 28.

26-Nov-1984 14:07:24

Execution time = 116 seconds

0696.SP

Vert = 5000 counts Disp = 1 Comp = 3

Rank Xerox 1045

Preset = 60 secs

Elapsed = 60 secs

NR. 28 PAPIER

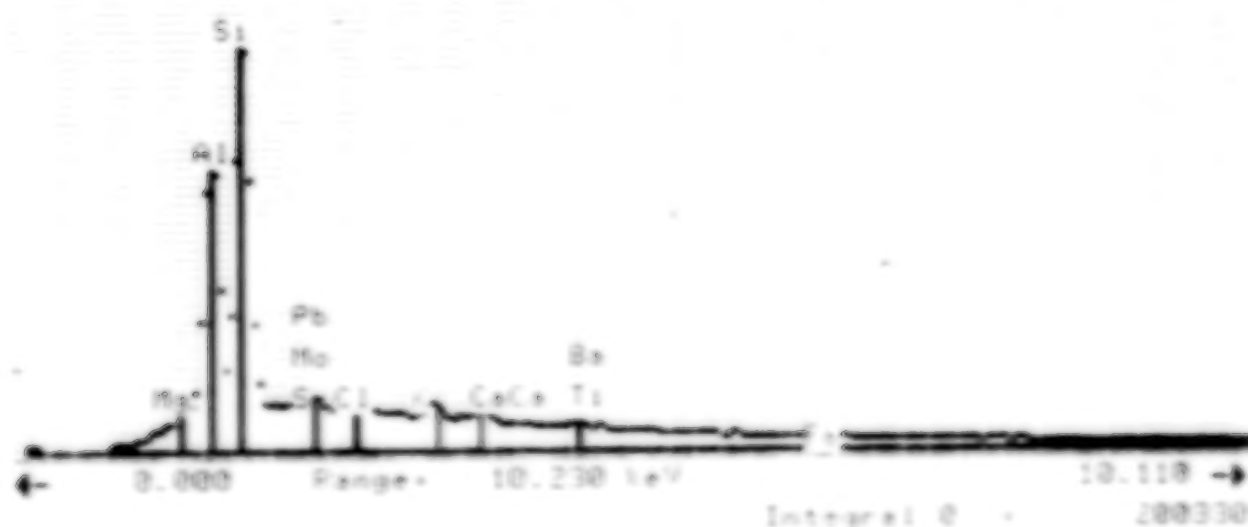


Figure 11. EDS X-ray spectrum. Same as Figure 10. Paper background. Note the corresponding integral counts in Figure 10.

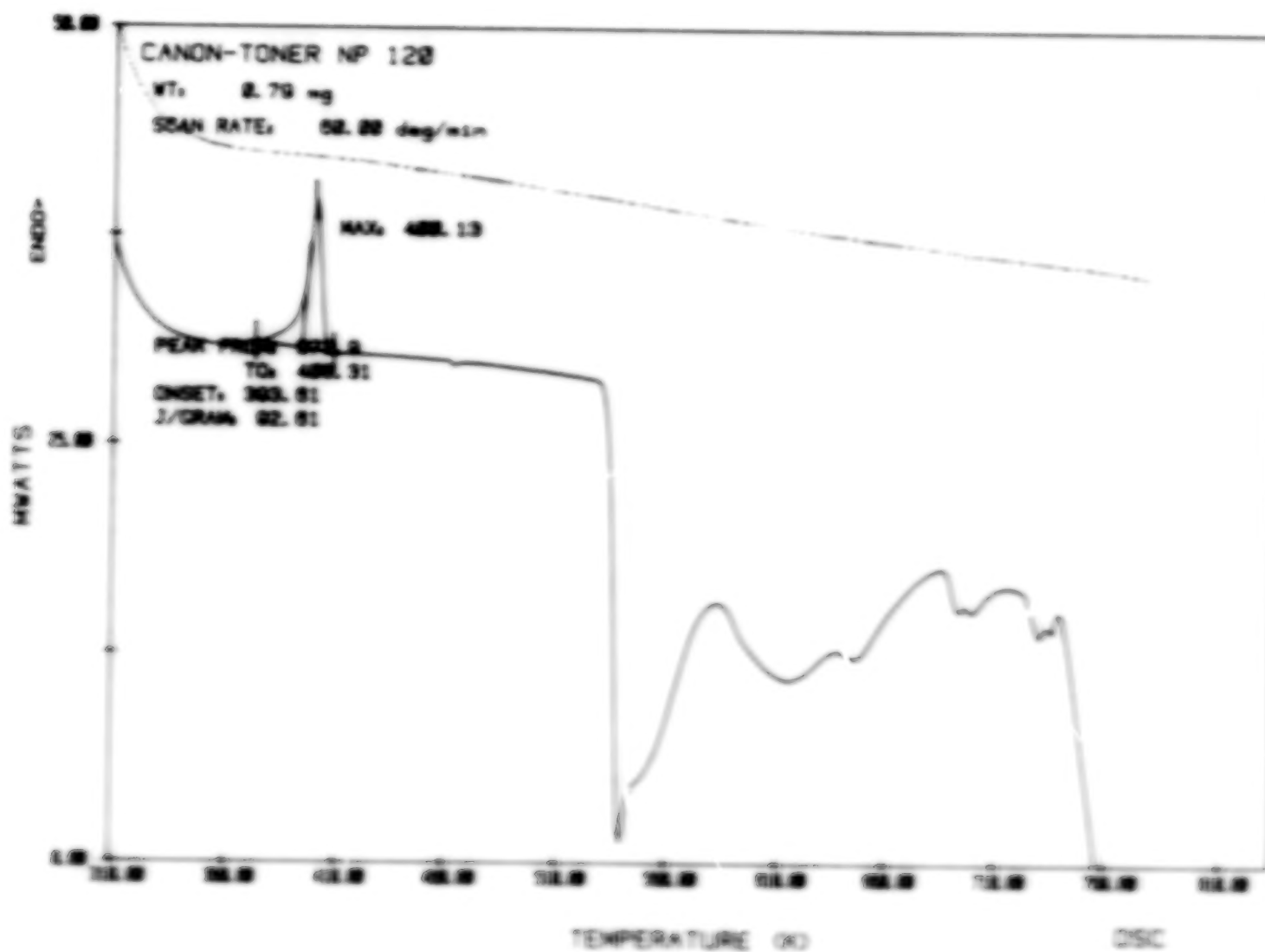


Figure 12. DSC curve of neoterebinthene resin. Strong melting peak and beginning of oxidation process at precise temperature. Sample weight 8.79 mg.

PLANK PAGE

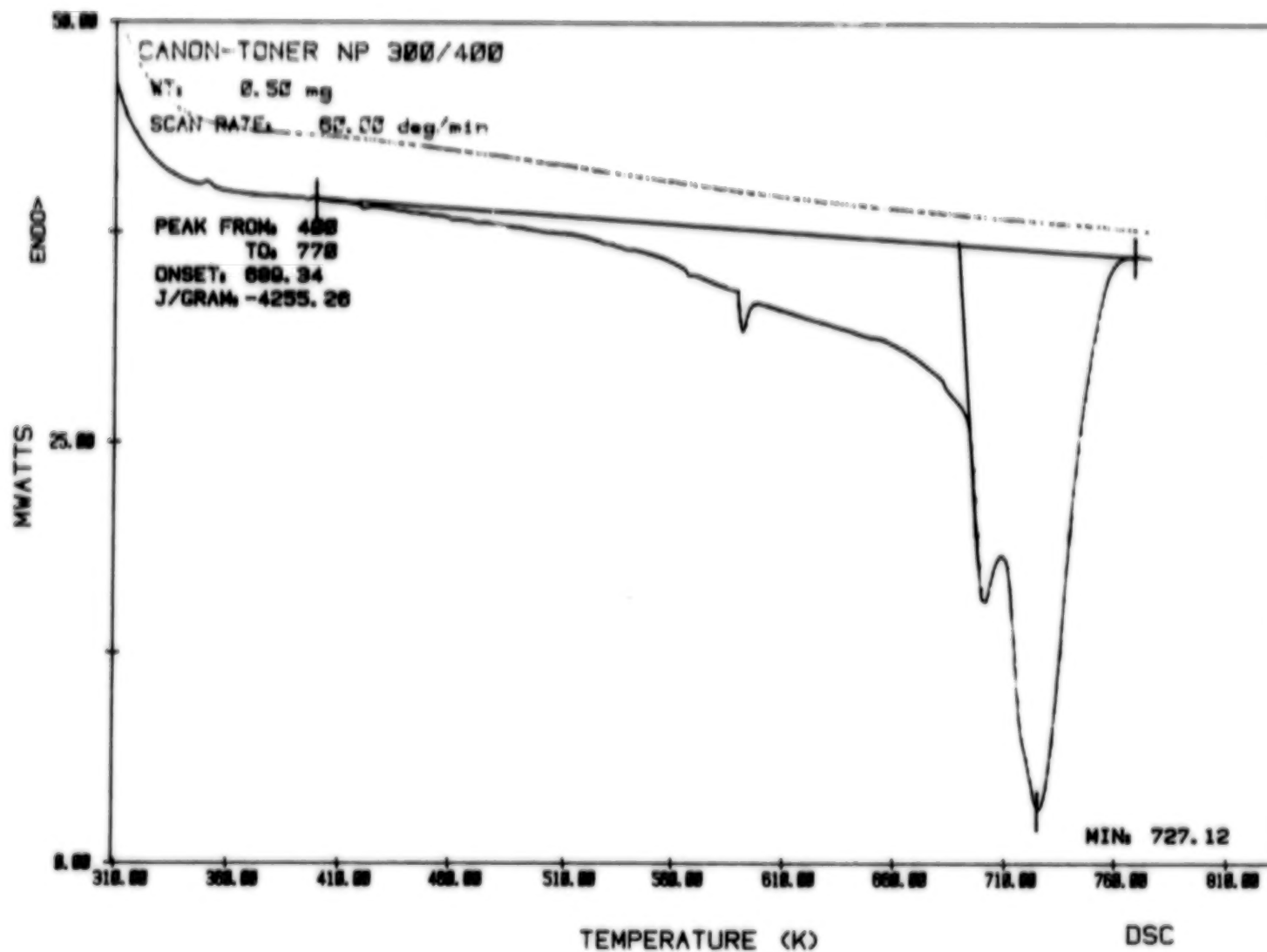


Figure 13. DSC curve of monocomponent toner. Same brand as Figure 12. Relatively weak melting peaks and oxidation processes at higher temperatures.

REFERENCES

- Corbobbese, P. et al. (1985).* L'identification des copies electrostatiques est devenue une realite, *Revue int. de criminologie et de police technique* 1:92.
- Heuser, H. G. (1984).* Zur Untersuchung von elektrophotographischen Kopierprodukten, *KT-Material Information* 3:129.
- Holland, N. W. (1984).* Photocopy classification and identification, *J. Forensic Soc.* 24:23.
- Horacek, G. and Müller, G. (1985).* Eine einfache Technik zur Untersuchung von Photokopietonern mittels der IR-Spektroskopie, *Archiv for Kriminologie* (to be published).
- Kemp, G. S. and Totty, R. N. (1983).* The differentiation of toners used in photocopy processes by IR-spectroscopy, *Forensic Sci. Int.* 22:75.
- Totty, R. N. and Baxendale, D. (1981).* Defect marks and the identification of photocopying machines, *J. Forensic Sci. Soc.* 21:23.
- Williams, R. L. (1983).* Analysis of photocopying toners by infrared spectroscopy, *Forensic Sci. Int.* 22:85.

BLANK PAGE

STATISTICAL INTERPRETATION OF METAL BEADS IMPARTED TO THE PRINTING SURFACE OF IBM SELECTRIC TYPE ELEMENTS

P. Marchand

Laboratoire de Police Scientifique
Montreal, Quebec, Canada

Various manufacturing flaws may affect IBM Selectric type elements. Among these flaws, microscopic metal beads fixed to the printing surface of any character are a powerful means of identifying a particular element. These raised beads, if sufficiently elevated, can puncture a hole through a carbon ribbon onto the paper. The comparison of a punctured document and an element may then result in a positive identification (Figure 1).

The purpose of this research project is (1) to demonstrate that the beads are of random origin and, consequently, highly specific, and (2) to determine the minimum number of beads an element must bear to be unique.

Two methods were employed to prove that the beads are of accidental (random) origin—examination of a selected sample of elements and dissection of beads. The selected sample was composed of 12 IBM Letter Gothic single elements (style number 81893 for Selectric III). Ten elements bore the same mold number, "3B" and the last two were coded "4H." The microscopic examination of the elements showed that each element disclosed a unique series of beads (Table 1). When the same character on two different elements bore a bead, the position of the beads allowed for differentiation (Figure 1).

Working under the microscope, the metal plating close to a bead was cut with a small milling cutter and

the metal piece bearing the bead was removed from the plastic matrix with the tip of a scalpel.

In every case, the surface of the plastic undercoat (matrix) was smooth throughout, as was the metal surface under the beads. The excised beads were then placed in concentrated nitric acid. A preferential action of the acid was observed on the surface facing the undercoat and at the junction of the bead and the metal. By stopping the reaction on time, some beads were found emptied of their contents, appearing like eggshells.

It is the author's opinion that the results of experiments A and B demonstrated that the beads do not appear to be a result of a flaw in the plastic matrix (undercoat) or, therefore, a flaw in the mold. The beads are probably a result of impurities encrusted in the metal coating during electroplating. This incidental process leads to a purely random positioning of the beads as was advanced by Leslie (1977). These observations lead us to the following statistical evaluation.

The statistical model consists in subdividing the total printing surface (S) of the characters on a single element in n surface units (u) and in calculating the number of different ways to distribute x beads in these areas with the formula $C_x^n = n! / ((n-x)!x!)$. This formula is valid for beads of random origin and undistinguishable from each other.

Table 1. RESULTS OF THE EXAMINATION OF A SELECTED SAMPLE OF IBM LETTER GOTHIC ELEMENTS BEARING THE SAME MOLD NUMBER.

#	Mold number	Number of beads	Characters bearing one or more beads	#	Mold number	Number of beads	Characters bearing one or more beads
1	3 B	1	B	7	3 B	40	B C E G H K S V W g l m o p q r s v w x z 6 7 : @ » # c / = + %
2	3 B	1	8	8	3 B	1	J
3	3 B	5	V & @ %	9	3 B	1	V
4	3 B	4	a e ? *	10	3 B	6	F L k O .
5	3 B	31	B E F G H I J K L M O Q S W b i j k v y 6 \$? %	11	4 H	1	M
6	3 b	None		12	4 H	None	



Figure 1. Two capital "E's" from the selected sample of IBM elements and their corresponding imprints. The relative position of the beads allows for easy differentiation.

These calculations were made for pica-sized characters (IBM Courier 10) and elite sized (IBM Courier 12) characters. The total surface (S) has been measured with a planimeter on photographs of characters taken at 25x. The surface unit (u) is a func-

tion of an examiner's capacity to distinguish without ambiguity two separate characters bearing a bead in the same area. Figure 2 shows that a surface unit of $0.2 \text{ cm}^2 \pm 0.1 \text{ cm}^2$ is within acceptable range. With a precision of 0.2 cm^2 , Table 2 indicates that there are

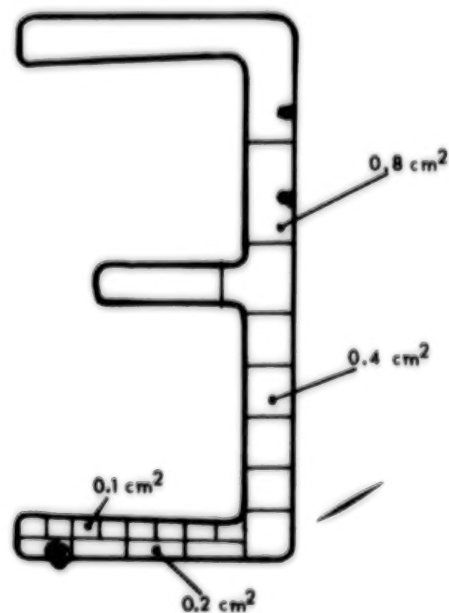


Figure 2. The surface of a capital "E" enlarged 25x has been divided into surface units of 0.1 cm^2 , 0.2 cm^2 , 0.4 cm^2 and 0.8 cm^2 . Summarily, a surface unit of $0.1\text{--}0.2 \text{ cm}^2$ is within acceptable range and units of 0.4 cm^2 and 0.8 cm^2 are too large.

Table 2. CALCULATION OF $C_x^n = n! / ((n-x)!x!)$

Courier 10 elements $S = 680 \text{ cm}^2 \pm 5\%$ at 25X

u	n	C_1^n	C_2^n	C_3^n	C_4^n
0,1 cm ²	6,800	6,800	12,116 600	$4,9345 \times 10^{10}$	$8,2840 \times 10^{13}$
0,1 cm ²	3,400	3,400	5,778,300	$7,7005 \times 10^9$	$6,4297 \times 10^{12}$
0,4 cm ²	1,700	1,700	1,144,150	$8,1739 \times 10^8$	$3,4687 \times 10^{11}$
0,6 cm ²	850	850	360,825	$1,0199 \times 10^8$	$2,1597 \times 10^{10}$

Courier 12 elements $S = 460 \text{ cm}^2 \pm 5\%$ at 25X

u	n	C_1^n	C_2^n	C_3^n	C_4^n
0,1 cm ²	4,600	4,600	10,477,700	$1,6212 \times 10^{10}$	$1,9037 \times 10^{13}$
0,2 cm ²	2,300	2,300	2,643,850	$2,0251 \times 10^9$	$1,1629 \times 10^{12}$
0,4 cm ²	1,150	1,150	660,675	$2,5281 \times 10^8$	$7,2495 \times 10^{10}$
0,8 cm ²	575	575	165,025	$3,1519 \times 10^7$	$4,5073 \times 10^9$

x = number of beads on the element.

n = S/u number of possible areas to distribute the beads.

S = total printing surface of an element, measured at 25X.

u = unit of area used to subdivide all the characters in order to differentiate the position of beads.

7,700,540,000 different ways to distribute (or disperse randomly) three beads on the surface of an IBM Courier 10 type element. In other words, the probability of finding two elements with three beads located exactly in the same positions is $1/(7.70054 \times 10^9)$.

CONCLUSION

The random position of beads can lead to statistical calculations to show that beads fixed to the printing surface of a single-element are highly specific.

One bead would not allow for the identification of a particular element; two beads could prove sufficient and three beads would lead to a positive identification.

REFERENCES

- Leslie, A. G. (1977). Identification of the single element typewriter and type element, Can. Soc. Forens. Sci. J., 10:87-101.

ACKNOWLEDGMENT

Mr. G. Leveault, Laboratoire de police scientifique de Montreal

BLANK PAGE

THE FEASIBILITY OF CLASSIFYING MODERN PRINTWHEEL TYPESTYLES

J. E. Behrendt and R. H. Muelhberger

U.S. Postal Inspection Service, Room 714
Memphis, Tennessee

Typestyle classification is a commonly employed method to determine the possible sources of a typewritten document and is particularly effective for typebar typewriters and single-element machines. The accuracy of source determination by typestyle classification of printwheels is a matter of question because of the limited amount of information on the compatibility of daisywheel printers and the extent of subcontracting by printwheel manufacturers. Three parameters were examined to study the feasibility of printwheel classification. The parameters chosen were the type of printwheel, the manufacturer of the printwheel and the manufacturer of the printer.

TYPE OF PRINTWHEEL

The type of printwheel has a definite effect on the typestyle. Spokes are lengthened, shortened, widened and narrowed, depending on the number of characters, the mount design and the sequence of the printwheel. This necessitates subtle changes in letter design to accommodate spatial considerations. Thus, two printwheels from the same manufacturer may bear different versions of the same typestyle depending on the printer for which the printwheel was designed. Additionally, the material from which the printwheel is made (monoplastic, dualplastic or metal) will affect the stroke width of the characters.

PRINTWHEEL MANUFACTURER

It is a common practice in the industry for a printwheel manufacturer to use both an internal and an external source of supply. For example, Diablo Systems, Inc., internally manufactures many of their printwheels through sole source contracts while simultaneously purchasing the same type of printwheel from outside

sources such as GP Technologies (GPT) and Caracteres SA (CSA). Although specifications are issued for the general wheel configuration, the outside sources are often free to use their own typestyles. These typestyles are then modified to accommodate the printwheel configuration. Thus, a Diablo Courier 10 printwheel for their Model 630 printer may differ in typestyle depending on the source from which it was obtained (Figure 1). Conversely, to classify an original equipment printwheel manufacturer such as GPT or CSA would require a sample of all the typestyle modifications for all of the manufacturers for which the typestyle was produced. Private label printwheels compound the problem (Figures 2, 3a and 3b). For example, Burroughs printwheels are manufactured by the ABL (formerly AGT), but also are distributed under the name of BetterType.

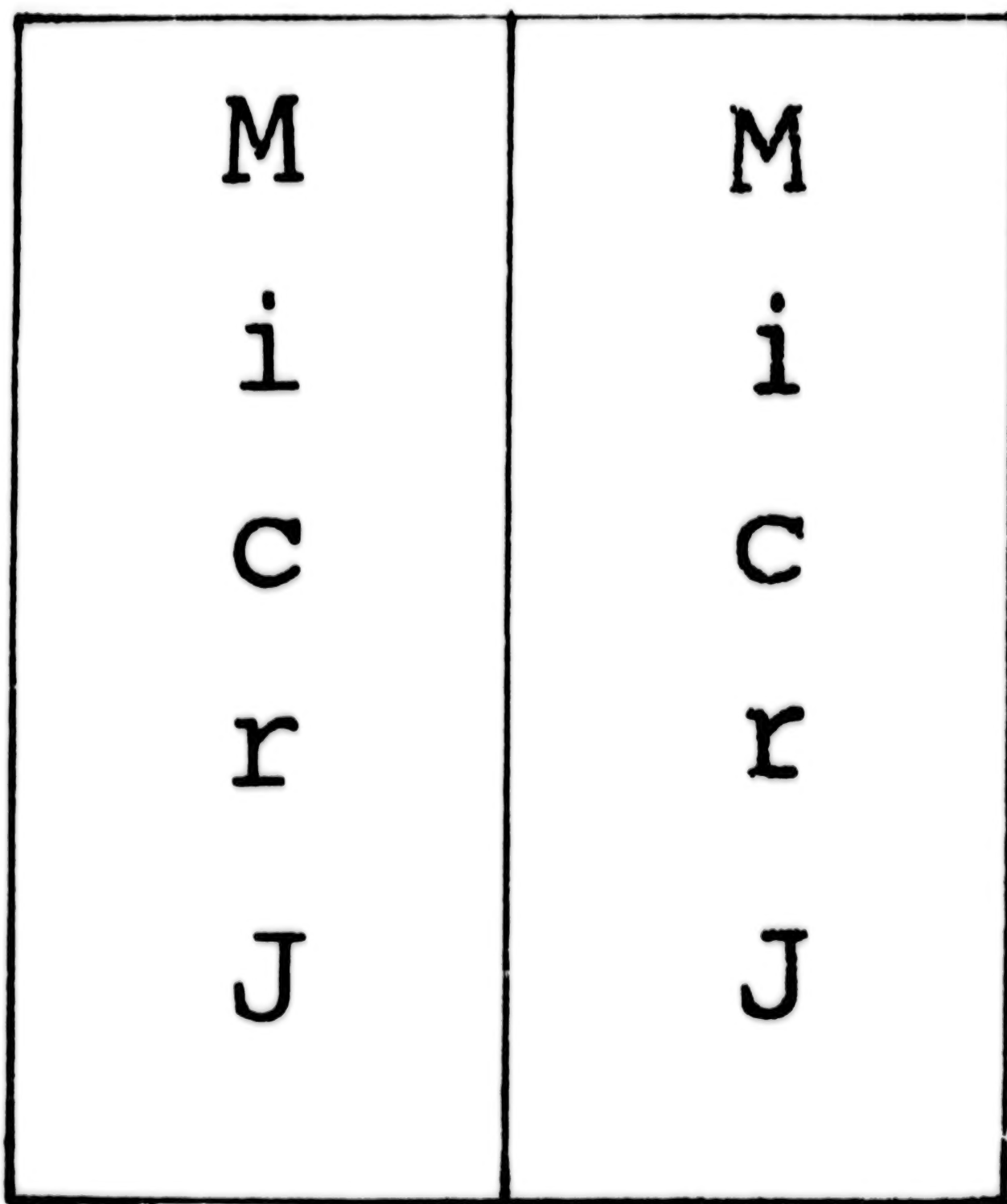
PRINTER MANUFACTURER

It is common knowledge that certain printwheels are interchangeable. For example, a Qume printwheel may fit a Diablo printer (Figure 4). Additionally, certain printer and electronic typewriter manufacturers purposely design their machines to accommodate another company's printwheel, then subcontract with that company to produce a private label printwheel (Figure 5). In both situations, typestyle classification gives no information about the source of the typewritten document.

CONCLUSIONS

With the continued rise in popularity of the printwheel, the problems of interchangeability, compatibility and multiple sources will increase. The result is that the classification of modern printwheel typestyles is no longer a feasible method of source determination.

DIABLO COURIER 10



620 PRINTER

630 PRINTER

Figure 1. Diablo Courier 10 printwheel.

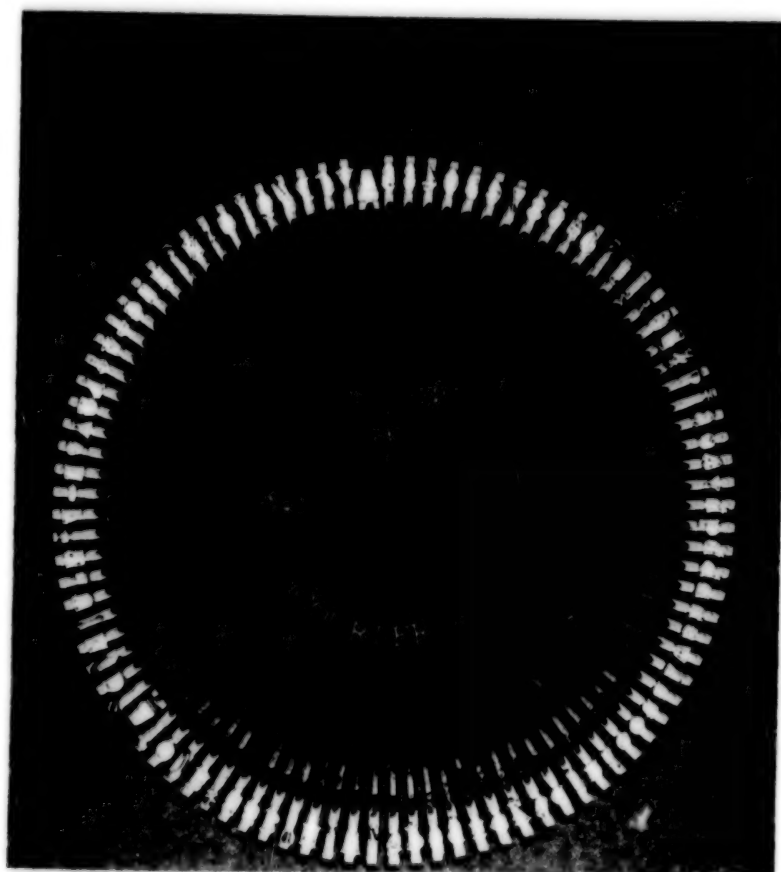
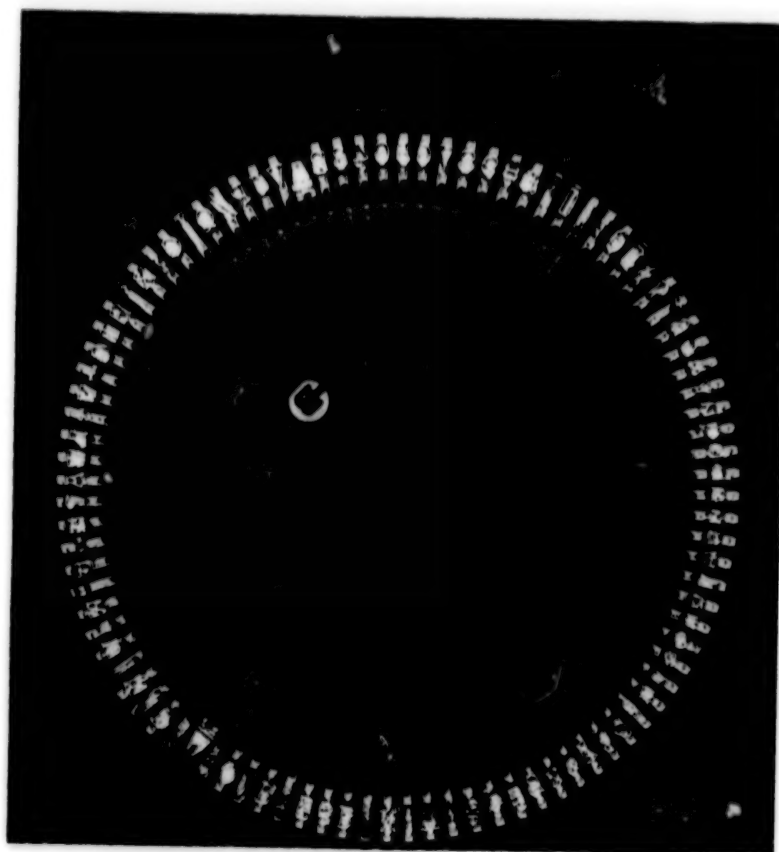


Figure 2. Burroughs and private label printwheels.

QWERTYUIOPASDFGHJKLZXCVBNM

qwertyuiopasdfghjklzxcvbnm

1234567890

!@#\$%&*()_+

,./;']

,.?:"[

BLANK PAGE

QWERTYU IO PASDFGHJKLZ XCVBNM

qwertyuiopasdfghjklzxcvbnm

1234567890

!@#\$%&*()_+

,./;']

,.?:"[

Figure 3b. Private label typesets.

EXAMPLES OF COMPATIBILITY

SEQUENCE

SEQUENCE

DIABLO USLEGAL 1 ——— QUME LEGAL 2

DIABLO USOCRA ——— QUME OCR-A 10 ANSI

DIABLO USOCRB ——— QUME OCR-B ANSI

JUKI (ALL) ——— TRIUMPH/ADLER (ALL)

Figure 4. Examples of compatibility.

MULTIPLE SOURCES

Q	Q
i	i
1	1
4	4
\$	\$

T/A COURIER 10

Figure 5. Multiple sources of Courier 10.

BLANK PAGE

FACSIMILE COPIES AS DOCUMENT EVIDENCE

T. E. W. Gayne

Bureau of Forensic Science
Richmond, Virginia

Facsimile copiers are increasingly being used in numerous applications to transmit documents related to the commercial and banking industries, including negotiables and contractual agreements. Research regarding facsimile copiers and copies was conducted with the transmission and copying of various types of document evidence, including handwriting, rubber stamps, typewriting and signatures from Autopens. Also, forgery methods such as tracings, simulations and transfer methods were experimented with to determine if the defects normally associated with forgeries would also be copied in the facsimile process. Various writing instruments were used in the study of these methods of forgery.

In addition to the handwriting aspects of this research, similar typewriter styles were copied by facsimile and examined under magnification to attempt to classify and/or differentiate the styles of type under scrutiny. Observations were made to compare serifs, position of the cross-strokes in the letters *f* and *t*, the position of the middle stroke in the capital letter *M*

and the formation of numerals. These features are commonly used to at least partially classify typewriting when using the Interpol System for Identification of Typewriter Makes Using the Card Index.

Since rubber stamps and other stamping mechanisms are routinely encountered on documents and are subject to fraudulent manipulation, facsimile copies of such impressions were compared with the original evidence. Characteristics found in rubber stamp impressions as copied digitally by facsimile machines show which features are recognized by the machine and how they are duplicated.

Further, since facsimile copies are derived from electrical scanning devices and transmitted through telephone lines and other means, there is opportunity for variation to be introduced not only from machine to machine, but also through subsequent copies of the same document over the same copier. These subtle characteristics occurring from copy to copy reveal the normal variation of the digital facsimile process. Their recognition by the document examiner is an essential facet of the examination of such copies.

BLANK PAGE

VIDEO SPECTROSCANNER SYSTEM: QUALITY ENHANCEMENT AND LOW COST IMPROVEMENT

S. Rivera and E. Flores

Puerto Rico Police Department
Forensic Crime Laboratory
San Juan, Puerto Rico

The use of infrared (IR) and ultraviolet (UV) radiation techniques in the questioned documents field is well known. Among the equipment using these techniques are some instruments that cost as much as \$100,000 or more. Richards (1977) presented a system known as Video Spectroscanner System (VSS) that can be used like the expensive ones, but costs much less.

This paper offers information on how to improve the VSS with a new device that can magnify the writing samples, converting the VSS to a system with microscope characteristics.

MATERIALS

1. TC 1005/UOI low-light camera with Ultricon II (silicon target) tube; automatic light range: 3.6 x 10 model 4532/U. RCA (Lancaster, PA).
2. V.25-0.85 lens. Manual super-fast standard 1 in. lens, f/0.85 fixed focal length RCA.
3. TC 1910 H.9 in. high-performance monitor, 900-line resolution RCA.
4. Wild multipurpose camera stand, table model with lamp carrier antivibration plate (52 x 34 cm) stock no. 273-344.
5. Mercury vapor light source or wild illuminator, 12V/100 w quartz-iodine.
6. Bellows with an extension range from 35 mm to 115 mm.
 - a. Schneider-Kreuznach Xenar lens 1:3.5/75 mm (no. 11274394) with magnification from 2x to 19x.
 - b. Tominon lens 1:4.5f/35 mm with magnification up to 65x.
 - c. Tominon lens 1:4f/17 mm with magnification up to 128x.
7. Filters.
 - a. Kodak Wratten gelatin 100 mm x 100 mm filters: 2c, 18A (glass), 87, 87A, 87B, 87C, 88A, 89B.
 - b. 10% copper sulfate filter.
 - c. Cobalt crystal filter.

In many cases we need to observe more closely the details usually seen through a stereoscopic microscope, which can magnify the writings 7x, 15x, 25x or more. This microscope, or even the most complex one, is not sensitive enough to differentiate between inks and does not register their reactions at different wavelengths. The VSS obviously becomes a valuable instrument to achieve this purpose in the questioned documents field, but it does not have the magnifying power of a microscope.

Using our instruments and not spending great amounts of money, we succeeded in adding to the VSS bellows that can increase the magnification of the sample image. These bellows, used by the Wild Image Converter M-500, installed on the video-spectroscanner camera instead of the normal lens, increase the image up to 128x approx. The Schneider-Kreuznach Xenar 1:35f/75 mm lens and the Tominon 1:45f/35 mm and 1:4f/17 mm lenses are ideal for obtaining close-ups without losing either details or resolution. The versatility of this accessory is depicted in Figure 1.

CONCLUSION

The magnification obtained with bellows is excellent in cases such as indentations and obliterations with different substances including correction fluid and some types of erasures made in documents. These bellows cost much less than a close-up lens or a microscope camera.

REFERENCE

- Richards, G. B. (1977).* The application of electronic video techniques to infrared and ultraviolet examination, *J. Forensic Sci.* 22:53-60.

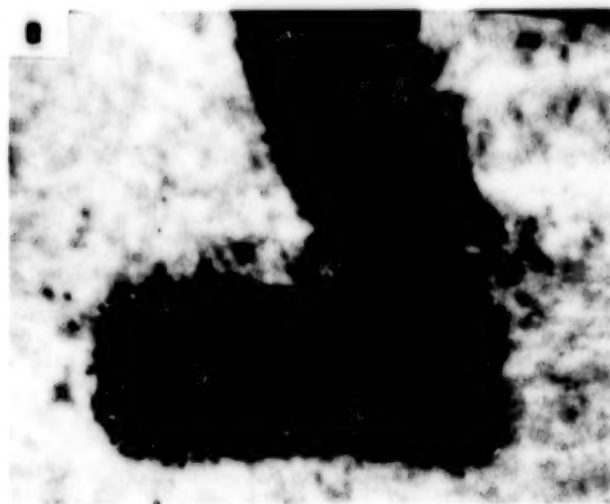


Figure 1. Example of how the bellows work with the 35 mm lens used in obliteration with increasing magnification in (a), (b) and (c), and with 17 mm lens in (d) and (e).

THE STUDY OF INVERTED MIRROR IMAGE WRITINGS THROUGH THE USE OF THE VIDEO SPECTRAL COMPARATOR

C. J. Raichle

U.S. Postal Inspection Service Crime Laboratory
New York, New York

The Video Spectral Comparator (VSC) has become an indispensable instrument in routine laboratory examination of obliterated writings and altered documents. Under normal circumstances, the area in question is examined using incident or transmitted light with the hope that through selection of the proper infrared or ultraviolet filters, the absorption or luminescence of the pertinent inks may yield positive findings.

When dealing with altered or obliterated documents, care should be taken not to restrict the examination to the crucial area or to regard inconclusive results as final. Scanning of the entire questioned document, front and rear, may produce unexpected and rewarding results.

A recent examination of a heavily obliterated signature on a 12-year-old sales receipt failed to penetrate the overwriting, but did show evidence of luminescent qualities in the underlying original writing. Only fragmentary unintelligible portions could be

perceived. In the area above the original signature, where no primary writings existed, some evidence of luminescence was seen. Using the inverted and mirror image capabilities of the VSC-1, a latent image was found to be the original customer's signature, which had been transferred to an opposite surface of the receipt after folding.

A Foster and Freeman VSC-1 using the infrared wavelength filter (FS-1) at 645 nm yielded best results in the related examination. Photography was accomplished using Polapan (ASA 12S) Autoprocess film in a Canon AE-1 program camera.

The existence of potentially valuable latent writings on seemingly unrelated surfaces cannot be overlooked. A complete examination of the entire questioned document and its preceding and following pages and consideration of the interior surface of an envelope or folder may reveal images made readily legible through the inverting and mirror image capabilities of the Video Spectral Comparator.

BLANK PAGE

ESDA AND THE POST-IT® NOTE

J. S. Tweedy

Minnesota Bureau of Criminal Apprehension
Forensic Science Laboratory
St. Paul, Minnesota

During a death investigation, it became necessary to examine two Post-it® notes to determine whether certain information had been added to them at a later date. Since there was reason to believe they had been prepared consecutively from one pad, an Electrostatic Detection Apparatus (ESDA) examination was made to see which writing, if any, had originally been on the notes. The results of the ESDA examination were confusing in the area of the adhesive. Tests were performed to see if the adhesive could affect an ESDA examination.

MATERIALS AND METHODS

The Post-it® note is a product of the 3M Company. It was test-marketed as early as 1977 and was distributed nationally in April 1980. It comes in many shapes, sizes and colors. Since November 1983, the company has included a 3M logo on the reverse of the notes. The most interesting aspect of the Post-it® note is its adhesive, which is repositionable and pressure-sensitive. This adhesive, located at the top of the back of the note, measures about 1/2 inch in depth and extends the full width of the note.

The testing procedure consisted of using different writing instruments and pressures on Post-it® notes and then running ESDA examinations on the underlying notes. The writing instruments used were pencils, ball point pens and felt-tip pens. The pressures were not accurately measured, but consisted of light, medium and heavy pressure as judged by the writer.

RESULTS

While most of the surface of the Post-it® note reacts in the expected manner, the area related to the adhesive does not. Regardless of the writing instrument used, the ESDA was not able to satisfactorily visualize any writing that had been produced over the adhesive. In the same manner, the various pressures used to produce the writing did not seem to affect the ESDA's reduced ability to visualize the indented writing.

The findings of Lewis (personal communication) were that the introduction of the ESDA imaging film or wax paper between the paper layers greatly reduced the amount of surface damage on the underlying layers and left no restorable indented writing. In the same manner, it would appear that the adhesive on the Post-it® notes substantially reduces the surface damage on underlying layers, thus making the ESDA unable to visualize the indented writing.

CONCLUSION

The Post-it® note exhibits a limitation in its ability to have indented writing restored from a portion of its surface. The area associated with the adhesive has a lowered ability to receive the surface damage necessary for the ESDA to visualize the indented writing. This limitation should be kept in mind when examining Post-it® notes by ESDA to avoid getting a false negative.

BLANK PAGE

VIDEO IMAGE ENHANCEMENT WITH THE FOSTER AND FREEMAN DIGITAL IMAGE PROCESSING SYSTEM

P. D. Bouffard

Regional Forensic Laboratory
Painesville, Ohio

The Foster and Freeman Digital Image Processing System (DIPS) is a commercially available video-processing system that is compatible with any synchronous black-and-white camera system. DIPS is especially useful when used in conjunction with the Foster and Freeman Video Spectral Comparator (VSC-1).

DIPS consists of a framestore, mixer and processor units, with optional cursor and profiler circuits and controls. The controls for the mixer, processor, cursor and profiler are on a self-contained keyboard unit. All functions are push-button controlled from this keyboard unit.

The mixer unit controls the image storage functions. Multiple image storage is accomplished using the gate function, with the location and size of the stored image controlled by positioning knobs on the keyboard unit. The inset function creates live windows within the stored image, with the window location and size controlled by the same positioning knobs that control the gate function. The mix function permits overlaying of live and stored images, with the stored image being a negative, allowing for subtraction of image areas that are identical in the live and stored images. The relative positions and intensities of the two images are controlled by knobs on the keyboard unit. The strobe function alternately displays the stored and live images to accentuate differences and similarities in the two images. The invert function reverses the black-and-white intensities of the stored image, producing a negative of the stored image.

The main enhancement functions of the processor unit include image stretch, accentuating differences be-

tween areas of low contrast, and edge sharpening, with selected computational masks, resulting in sharpening of "wooly" images to varying degrees.

The following typical image enhancement functions are demonstrated in this paper:

1. Contrast enhancement of faint carbon images using the stretch function to darken the line and the edge function to accentuate differences.
2. Enhancement of carbonless images by storing the far-red luminescent image, followed by image inversion to produce a black-on-white image, and selected edge functions to sharpen the image.
3. Deciphering of covered images (typewriter correcting fluid), using Freon to transparentize the paper (from the reverse side), storage of the faint image and enhancement using the stretch and edge functions. The image is made right-reading using the mirror control on the video monitor.
4. Removing interfering overwriting or stamps, using a mix of a stored infrared image and a live visible image, controlling the intensities and position of the two images to subtract the infrared image, leaving only those areas that are infrared transparent.
5. Three-dimensional effects for image enhancement, using the mix function to produce an overlay of a live and stored image, offsetting the two images and controlling intensity to produce the appearance of indented or raised images.
6. Multiple image storage with insets of live images. The stored image areas can be edge sharpened, or enhanced in any of the above described ways to provide better images.

BLANK PAGE

SUSPECT ART/SUSPECT DOCUMENTS: A CASE STUDY OF PARALLEL TECHNIQUES AND EXAMINATIONS

C. Mercer

Indiana State Police
Indianapolis, Indiana

A pictorial look was made of the methods, techniques, instrumentation and possible conclusions in the examination of forged art as they parallel the examination of suspect documents. Similar methodology is used to probe through an illusion created to project authenticity about the alleged artistic creations of a noted artist as those used to disprove the genuineness of a suspect document. Microscopic, infrared, ultraviolet, X-ray and chemical treatments are used to determine source, authenticity and sequence of use of the various components used to create the item in dispute. This particular case study illustrates the similarity of the various instrumentation used for the art/document examinations, as well as development and research of observations about suspect components and their meaning in the overall makeup of the object.

An overall observation assessment of the art objects yielded general pieces of data to analyze. These findings included materials that were not in existence at the time the object was purported to have been produced, artificial aging, obliterations, simulations, sequence of execution and a conclusion that the ability of the forging painters was inferior to that of the true artists.

The oil paintings were subjected to a mild solvent such as naphtha, xylene or toluene and were found to be soluble. With any painting from around the turn of the century, as these purported to be, the oils would have oxidized and undergone a complete chemical change and would no longer be soluble in such mild solvents.

Simulated crackle patterns were found to be present in one of the paintings. As the oils harden, actual cracking can occur, which coincides with age. Microscopic examination of the crackle revealed superficial cuts in the top surface of the paint, which were made with some type of cutting or scribing device, and were not complete cracks through the paint.

Staples and staple holes were found in very pliable canvas purporting to be of 1913 vintage. Canvas of that age would have been stiff and brittle. Also, tacks were used at that time period and staple guns were not. Restretching of the canvas using modern staples would have left empty tack holes instead of other empty staple leg holes with impressions of the staple bodies in the canvas.

Artificial aging was attempted by antiquing the backs of the canvas to simulate an accumulation of years of dirt. Flicking small spots onto the face of the painting with antiquing to simulate fly specks was also found, again to suggest age.

One particular painting seemed to encompass several pieces of evidence that would result in the conclusion it was not genuine. The painting, dated Munich 1884, was mounted with a liquid adhesive to a piece of masonite. Masonite did not come into existence until the 1920s. That alone is not conclusive. Additionally, the liquid adhesive was found to have squeezed out the edge of the canvas onto the side of and around the back of the masonite. Oil paints on the front of the canvas were found to continue off the edge of the canvas and onto the hardened adhesive on the side and back edge of the masonite. An X-ray of the painting revealed another painting, not by the subject artist, under the newer one.

An individual point discovered about one of the paintings or any questioned document by itself may not produce conclusive findings. Together with multiple points, their weight could overwhelmingly conclude a forgery. Methodology, techniques and instrumentation are parallel in the art and document fields to the point where a judgment is called for on the ability of the artist. At that point, the road bifurcates and it becomes necessary for a specialist in the art field to evaluate based upon his training and experience with works of art.

BLANK PAGE

SECTION III
PANEL DISCUSSION

BLANK PAGE

PANEL DISCUSSION TRAINING THE DOCUMENT EXAMINER

MODERATOR: *Tom Dewan*, FBI Laboratory

PANEL MEMBERS: *Lynne Bonjour*, U.S. Postal Inspection Service Laboratory
David Crown
Manfred Hecker, Bundeskriminalamt
A. G. Leslie, Royal Canadian Mounted Police Laboratory
Richard Toddy, Home Office Forensic Science Laboratory
Ted Whitcomb

The panel's purpose was to compare training programs for document examiners, to examine the educational and occupational backgrounds of examiners, and to discuss certification and regulation of examiners.

The panel opened with a comparison of training and testing programs for document examiners in the United States, the United Kingdom, Canada, and the Federal Republic of Germany. The programs range from 2 to 3 years in length. The degree of formality ranges from a very structured course of study punctuated by frequent written and oral tests to a hands-on approach in which trainees work on cases from the start, with senior examiners reviewing and critiquing their work. Most of the programs offer some combination of reading, case work, and moot courts, followed by work under supervision, leading up to independent work and court testimony.

One area of considerable variation is amount of training required before an examiner may testify in court. The American Board of Forensic Document Examiners (ABFDE) requires completion of a 2-year training program plus 2 years of case work before examiners may testify. In Germany, examiners must complete a 2-1/2-year training program before testifying. In the United Kingdom, examiners must be trained by the Home Office in order to testify in criminal cases, but no such training is required to testify in civil cases.

There is a definite current toward formalizing the training process. Initially approximately 90 percent of the diplomates certified by the ABFDE were "grandfathered in" to form a nucleus of qualified document examiners. The board's original goal was that by the year 2000 all examiners would be certified by the board. Both Canada and the United Kingdom have moved toward longer, more formal training programs.

Is an undergraduate degree a prerequisite to becoming an examiner? In earlier years, people without degrees entered the field and were successful. Now, however, a bachelor's degree is required for membership in the American Academy of Forensic Sciences and the American Society of Questioned Document Examiners. Advanced degrees are desirable, as it is hoped that examiners will be qualified scientists. The

panelists from other countries also expressed a strong preference, if not a requirement, for an undergraduate degree. The preferred fields are psychology, which offers information on physiology, statistics, psychiatry, and the effects of illness on handwriting, or one of the physical sciences.

A background in law enforcement may be a help or a hindrance. It enables examiners to appreciate field conditions and to understand what investigators need. It also exposes them to court experience. In the United Kingdom and Germany, however, testimony in criminal cases is more likely to be perceived as objective if the examiner is not associated with a law enforcement agency.

Private individuals or those who work for forensic laboratories may choose to call themselves examiners on the basis of little experience or training. They may be licensed, but licensing merely involves paying a fee to practice. In the United States, a simple criterion for determining private examiners' qualifications is membership in the American Academy of Forensic Sciences and the American Society of Questioned Document Examiners, and certification by the ABFDE.

The existence of certification programs raises the question of how to decertify incompetent or unethical examiners. Training programs help to filter out the incompetent. In most cases, the government laboratories that employ examiners police them, helping to eliminate the unethical. Still, groups that certify examiners must also be prepared to decertify them if the need arises. Both in the United States and abroad, decertification involves proof of gross error or intentional wrongdoing.

Jim Kelly, of the American Board of Forensic Document Examiners, explained the board's procedure for dealing with certified examiners whose competency is questioned. The board collects testimony and holds a hearing on the complaint. It then appoints three to five people to review the evidence and make a determination. If the examiner is found to have been in error, the board may issue an oral reprimand, a written reprimand, a suspension, or a decertification, depending on the gravity of the situation.

At present, it is not difficult for poorly qualified practitioners to be accepted by courts as expert witnesses. However, aggressive cross-examination often discredits the testimony of so-called "experts." ABFDE is campaigning to raise awareness of document examiners' qualifications among the legal profession. One way to educate the courts is for board-certified

examiners to so identify themselves, reinforcing the concept of document examination as a profession.

It seems likely that the relatively young profession of document examiner will benefit from more structured training, formal certification, and wider recognition in the future.

PARTICIPANTS

Robert W. Bassemir
Sun Chemical Corporation
631 Central Avenue
Carlstadt, New Jersey 07072

James E. Behrendt
Southern Region Crime Laboratory
U. S. Postal Inspection Service
1407 Union Avenue
Memphis, Tennessee 38161

Lynne Bonjour
U. S. Postal Inspection Service
475 L'Enfant Plaza
Washington, DC 20260

Philip D. Bouffard
Regional Forensic Laboratory
27 Woodland Road
Painesville, Ohio 44077

Thomas E. Dewan
FBI Laboratory
JEH-FBI Building
Washington, DC 20535

Donald L. Elbert
International Business Machine Corporation
740 New Circle Road, D75 Building 032-3
Lexington, Kentucky 40505

Thomas E. W. Goyne
Bureau of Forensic Science
Northern Virginia Regional Laboratory
P. O. Box 486
Merrifield, Virginia 22116

Michael P. Gryzik
Orange County Sheriff-Coroner Department
550 N. Flower Street
Santa Ana, California 92702

Robert G. Hacker
Rochester Institute of Technology
One Lomb Memorial Drive
Rochester, New York 14623

Manfred Hecker
Bundeskriminalamt
Kriminaltechnisches Institut
Postfach 1820,
D-6200 Wiesbaden
Federal Republic of Germany

H. G. Heuser
Bundeskriminalamt
Kriminaltechnisches Institut
Postfach 1820,
D-6200 Wiesbaden
Federal Republic of Germany

Griff Howell
Fox River Paper Company
P. O. Box 2215
Appleton, Wisconsin 54911

Dwight R. Howes
New York State Police Crime Laboratory
Building 22, State Campus
Albany, New York 12226

Howard J. Humecki
W. C. McCrone Associates, Inc.
2820 S. Michigan Avenue
Chicago, Illinois 60616

Elizabeth L. James
FBI Laboratory
JEH-FBI Building
Washington, DC 20535

Donald W. Johns
International Business Machine Corporation
740 New Circle Road, D75 Building 032-3
Lexington, Kentucky 40505

Rick P. Johnson
Bureau of Forensic Science
Northern Virginia Regional Crime Laboratory
P. O. Box 496
Merrifield, Virginia 22116

Eugene J. Levy
Chemical Data Systems, Inc.
7000 Limestone Road
Oxford, Pennsylvania 19363

Franklin P. Lundblad
U. S. Postal Inspection Service
475 L'Enfant Plaza
Washington, DC 20260

Pierre Marchand
Laboratoire de Police Scientifique
1701 rue Parthenais
C.P 1500, Station C
Montreal, Quebec, Canada H2L 4K6

Robert R. Massey
Anja/Scripto, Inc.
1016 South Mountain Avenue
Monrovia, California 91106

Charles McGinnis
FBI Laboratory
JEH-FBI Building
Washington, DC 20535

Clarke Mercer
Indiana State Police
100 N. State Avenue
Indianapolis, Indiana 46204

Dale M. Moreau
FBI Laboratory
FSRTC
FBI Academy
Quantico, Virginia 22135

Peter J. Nolan
Metropolitan Police Forensic Science Laboratory
109 Lambeth Road
London, England SE1 7LP

John W. Piper
U. S. Secret Service
1800 G St. NW
Washington, DC 20223

Carl J. Raichle
U. S. Postal Inspection Service Crime Laboratory
90 Church Street, Room 1316X
New York, New York 10007

Saul Rivera
Criminal Laboratory Division
Puerto Rico Police Department
G. P. O. Box 70166
San Juan, Puerto Rico 00936

Arthur Schlang
115 Skyline Drive
Coram, New York 11727

Craig L. Schlinz
FBI Laboratory
JEH-FBI Building
Washington, DC 20535

C. Thomas Spitzer
FBI Laboratory
JEH-FBI Building
Washington, DC 20535

Richard N. Totty
Home Office Forensic Science Laboratory
Usk Road
Chepstow, Gwent, NP6 6YE, England

Janis S. Tweedy
Minnesota Bureau of Criminal Apprehension Laboratory
1246 University Avenue
St. Paul, Minnesota 55104

D. Varshneya
Babcock and Wilcox
1562 Beeson Street
Alliance, Ohio 44601

Janis M. Winchester
Florida Department of Law Enforcement
P. O. Box 1489
Tallahassee, Florida 32302

Jeannine Zimmerman
Aurora Police Department
15001 E. Alameda Drive
Aurora, Colorado 80012

AUTHOR INDEX

- | | | | |
|----------------------|---------------------|-------------------------|---------------------|
| Bassemir, R. W., 13 | Hecker, M., 97, 185 | Levy, E. J., 141 | Schlang, A., 105 |
| Behrendt, J. E., 163 | Heuser, H. G., 145 | Lundblad, F. P., 101 | Schlinz, C. L., 71 |
| Black, M., 125 | Howell, G., 3 | Marchand, P., 159 | Spitzer, C. T., 119 |
| Bonjour, L., 185 | Howes, D. R., 129 | Massey, R. R., 7 | Toddy, R., 185 |
| Bouffard, P. D., 179 | Hubbleday, E., 49 | Mercer, C., 181 | Totty, R. N., 49 |
| Crown, D., 185 | Humecki, H. J., 131 | Metcalf, G. S., 49 | Tweedy, J. S., 177 |
| Dewan, T. E., 185 | James, E. L., 27 | Mooney, D., 139 | Varshneya, D., 111 |
| Elbert, D. L., 21 | Jeffers, L. A., 111 | Muelhberger, R. H., 163 | Wampler, T. P., 141 |
| Flores, E., 173 | Johns, D. W., 25 | Noblett, M. G., 111 | Winchester, J., 137 |
| German, B., 49 | Johnson, R. P., 127 | Nolan, P. J., 83 | Zimmerman, J., 139 |
| Goyne, T. E. W., 171 | Kemp, G. S., 49 | Piper, J. W., 79 | |
| Gryzik, M. P., 125 | Kimmet, M. J., 139 | Raichle, C. J., 175 | |
| Hacker, R. G., 33 | Leslie, A. G., 185 | Rivera, S., 173 | |

BLANK PAGE

SUBJECT INDEX

American Board of Forensic Document Examiners (ABFDE), 185

APPITA (Australian Pulp and Paper Industry Technical Association), 6

Art

counterfeit, 181

stolen, 119-121

ASTM (American Society for Testing and Materials), 6

BPBMA (British Paper and Board Makers Association), 6

Bundeskriminalamt (BKA), 97

Bureau of Alcohol, Tobacco and Firearms (ATF), 9, 12

Certification of examiners, 185

Chromatography

gel permeation, 17-18

thin layer (TLC), 8, 9, 10, 11, 81

pressure liquid, 81

vapor phase gas, 8-9, 10, 11, 20, 139, 141

Computer

crime, 71-76

printers, 72-76, 79

print technology classification, 137

text processing, 97-99

Counterfeit

art, 181

credit cards, 79, 81-82, 127

currency, 79-81

documents, 82, 181

CPPA-TS (Canadian Pulp and Paper Association, Technical Section), 6

DB database, 27

Digital Image Processing System (DIPS), 179

Electrostatic Detection Apparatus. *See* ESDA

Energy dispersive X-ray (EDAX), 15, 20, 68, 146, 151-154

ESDA, 101-104, 177

Facsimile copiers, 171

Fingerprints, 82, 86

Flexography, 36-38, 48

Fluorescence, 111-118

Fourier transform infrared spectroscopy (FTIR), 20, 49

Gas chromatography (GC), 20, 141

Gas chromatography mass spectrometry (GC/MS), 20, 141, 143

Gel permeation chromatograph (GPC), 17

Gravure. *See* Intaglio

Handwriting, 71, 72, 82, 97-99, 171

Hologram, 82, 127

Ink

additives, 19-20

aging, 131

analysis, 13-20, 81, 141-143

ball-point pen, 7, 8, 9, 11, 131-135

colorants, 19

composition, 13-20

erasable, 11

formulation, 15-17

glycol-based, 7, 8

jet printers, 22-23, 75-76

laser scanning, 111-118, 125-126

manufacturing, 8

marker, 9, 10

oil-based, 7, 8

permanent, 10

printing, 13-20

quick dry, 7, 8

rare earth date tags in, 9, 12

typewriter, 21-23

vehicle chemistry, 17-19

water-based, 9, 10, 11

Intaglio, 13, 15-17, 40-43, 48

Key punch machines, 74-75

Laundry markers, 11

Lithography, 13, 15-16, 38-40, 48

Luminescence imaging, 111-118. *See also* Spectroscopy

Luminescence Imaging Document Analyzer (LIDA), 111-118

Microspectrophotometer, 81

National Institute for Occupational Safety and Health (NIOSH), 101

National Printing Ink Research Institute (NPIRI), 20

Occupational Safety and Health Administration (OSHA), 101

Office machine copiers (OMCs), 80

Optical character reader (OCR), 71

Paper

analysis, 3-6, 80, 141-143

coated, 27, 137

dimension, 68, 137

examination, 71

manufacturing, 3-6

photocopy, 27, 30

plain, 27, 137

source document, 71

stock, 35, 71

supply, 30

Pencil, 129

Pens, 7-12, 83, 92-94, 129

Phosphorescence, 111-118

Photocopy

- alteration, 72
- characteristics, 80
- classification, 145-157
- color, 31, 80
- machines, 27-32
- paper, 27, 30
- toner, 27, 49-69, 80, 139, 145-157

Physical developer (PD), 84

Post-it® note, 177

Printing processes

- characteristics, 33-48
- flexography, 36-38, 48
- intaglio, 13, 15-17, 40-43, 48
- laser printer, 75, 79
- letterpress, 13-16, 33-38, 48
- lithography, 13, 15-16, 38-40, 48
- offset lithography, 38-40, 48, 79, 81, 127
- raised image, 44-46
- screen-process, 43-44, 48
- silk-screen, 43, 81, 127
- steel-die engraving, 44, 48
- thermography, 44-46

Pyrolysis

- inks, 139, 141-143
- paper, 139, 141-143

Rubber stamps, 71, 72, 171

Scanning electron microscopy (SEM), 6, 15, 20, 52, 53, 68-69, 83-95, 145-149

SCAN (Scandinavian Pulp, Paper and Board Testing Committee), 6

Solvents

- glycol, 8, 9, 10, 11
- hydrocarbon, 11, 52
- ink, 7, 10, 11, 17, 19

non-volatile, 8

organic, 5

permanent ink, 10

strong, 20

Spectrophotometry

infrared, 68, 139

Spectroscopy

- infrared, 8, 9, 10, 11, 20, 49, 139
- ultraviolet-visible, 8-9, 10, 11, 20

TAPPI (Technical Association of the Pulp and Paper Industry), 5

Thermography, 44-46

Triglycine sulfate (TGS), 131

Typewriter

- IBM Selectric, 25-26, 159-161
- impression comparison, 83, 105-110
- Interpol System for Identification, 171
- manufacturing, 25-26
- printwheel typestyles, 163-169
- ribbons, 21-23, 89, 92, 94
- styles, 171

Ultraviolet

- ink curing, 17, 19
- radiation techniques, 173
- visible spectroscopy, 8-9, 10, 11, 20, 181

Video Spectral Comparator (VSC), 129, 175, 179

Video Spectroscanner System (VSS), 173-174

Watermarks

- dandy, 5, 80
- directories, 5, 80
- mill brand, 5
- rubber-stamp, 5

Writing

- sequence of, 83-95, 129

END

FILMED

09 / 09 / 92